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Thin steel sheets – Most widely used material in packaging industry

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----------ABSTRACT----------
In present time, among the most frequently used packaging materials such as plastics and glass, there are also very often used steel materials. This material thanks to its excellent properties such as easy recycling and wholesomeness belongs to the highly preferred materials. The requirements for packaging steel sheets are same as in the automotive industry, for example reduction of the thickness, reduction of thickness of coatings and increasing their lifespan. These requirements are changing according to the market. Also thanks to its recycling and health neutral properties this material is suitable for wide use in packaging industry.

Keywords: *packaging steels, recycling of steel sheets, present state in packaging*

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I. INTRODUCTION

Thin steel sheets have been used for the production of packagings for more than 100 years. Production of packagings, as well as the production of steel sheets used for the production of packagings, has considerably changed over this period of time. Until the second half of 1980s, most of the steel worldwide was produced by a traditional billet casting method. Billets were consequently divided and rolled in horizontal and vertical rolls (so called slabbing) where the slabs were produced. Slabs were after that processed by cold and hot rolling. Developments in the field of packaging materials have also been a major concern in recent decades for thin tin-plated steel sheets, which are the most used material in the packaging industry. This raises the need for further refinement, with an emphasis on the quality and economy of their production. In some areas of this sector, packaging sheets are almost irreplaceable material. Thin tin-plated steel sheets are produced by the second reduction technology preceded by recrystallisation annealing [1, 2]. These materials are a relatively inexpensive, lightweight and durable with good properties that make it the leader in the field of packaging materials. Their use is versatile but they are mainly applied in the food industry, for its corrosion resistance and health-neutral properties, as well in the automotive industry. Packaging sheets are most often processed by forming technology. It is due to their high formability. The high life of the packaging materials is ensured by the tin coating, which ensures their resistance to adverse effects. Steel as a packaging material is currently a promising alternative to non-metallic packaging materials.

II. THE USE OF PACKAGING STEELS AND THE TEMPORARY STATE

World production of packaging material represents a major part of production in this industry sector. The packaging steel sheet asks for the basic criteria and requirements for its use to be met. The first essential requirement is the good processability and formability of the material to ensure the proper behavior of the material when it is processed. The second criterion, since steel material is subject to corrosive environmental influences, is its high durability and lifespan, which is ensured by applying thin tin or polymer coatings to the surface of the material. The percentage utilization rate of this material indicates the greatest use in the food industry of 58% of total production. Further utilization of this material is found in the production of beverage cans, various caps and special applications in the manufacture of industrial containers due to their suitable properties. The wide application of thin packaging materials is shown in Fig. 1[1, 2]

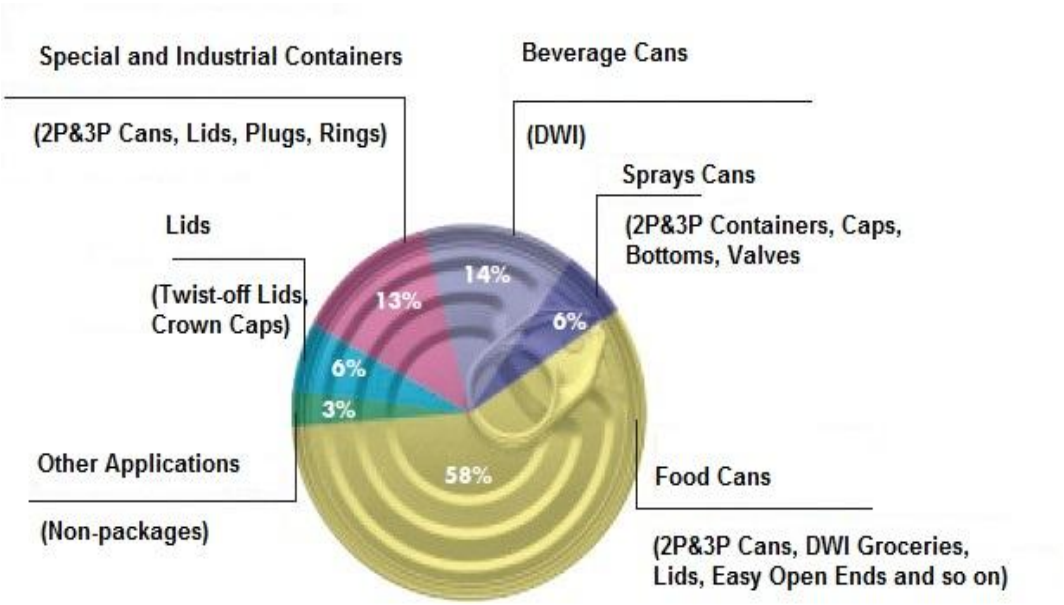

Fig.1 The use of packaging steels [3]

As in the automotive industry, the requirements for steel sheets are also increasing in packaging industry. This is due to the increasing consumption and utilization of these materials while ensuring their flawless properties. A significant advantage of steel materials in terms of their own production is their very simple and cost-effective recyclability. Steel is the world's most recycled material used in the packaging industry. About 72% of recycled packaging material is steel in Europe and this figure has doubled in the last 10 years. When reusing this material in the steel production process, steel does not lose even the smallest percentage of the quality of its properties. For this reason, the use of old steel for recycling is a never-ending process. Higher useage of recycled steel produces lower CO2 creation than steel with a higher proportion of primary raw materials. In fact, every product made of recycled steel saves one and a half times the CO2 mass. Industrial production of CO2 has fallen by 50% in the area of steel production compared to the state more than 40 years ago. Figures 2 and 3 show the recyclability of the most used packaging materials in Europe in 2015. [2, 3]

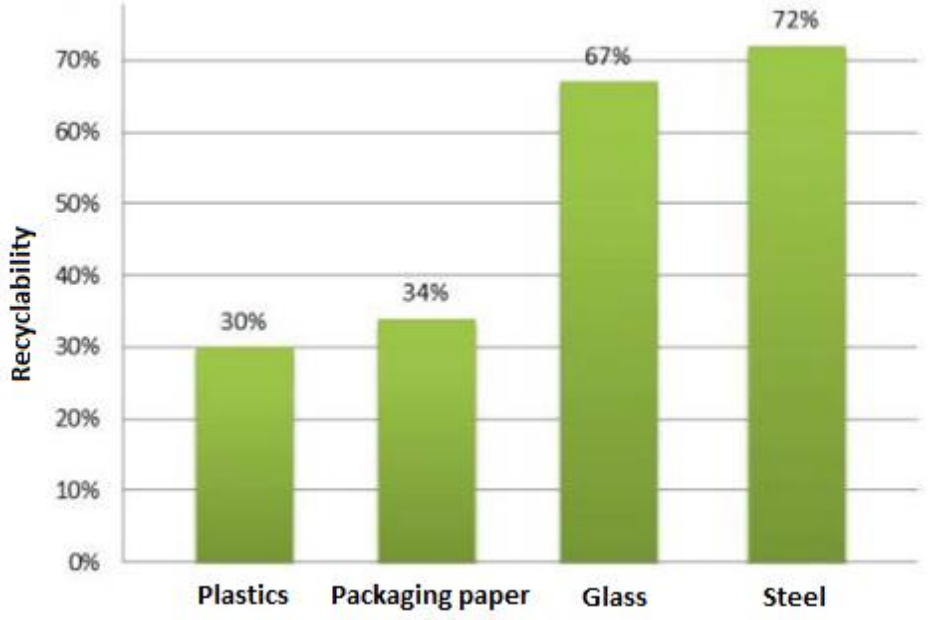

Fig.2 Volume of recycled packaging materials in Europe in 2015 [3]

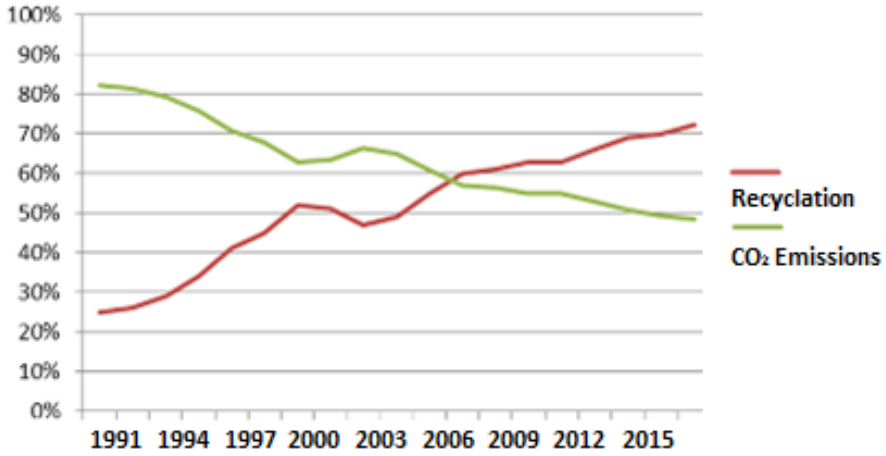

Fig. 3 Comparison of recycling and reduction rates of CO_2 [3]

Other trends are copying the situation in the automotive industry, namely production efficiency, reducing the cost of material production, while increasing the life and quality of the material. This fact is closely related to the reduction of the thickness of the thin packaging steel sheets and to the reduction of the thickness of their protective coatings. In the 30-year time horizon in this manufacturing sector, the material thickness was reduced by 25% in a rapid improvement of their properties and service life. This represents a substantial drop in the material needed for the production of packaging materials and hence a decrease in production costs. The reduction in the cost of packaging material production was also underlined by the actual process of steel production, the primary raw material. Over the last 50 years, significant improvements have been made in the cost of producing one ton of steel, representing a saving of 40% of the energy consumed. In order to optimize the use of energy in the steel production process, extra resources are used, for example residual heat and gases, which is a further increase in production efficiency. Figure 4 shows a decrease in the weight of a 425 ml food package at a horizon of approx. 30 years. [2, 3]

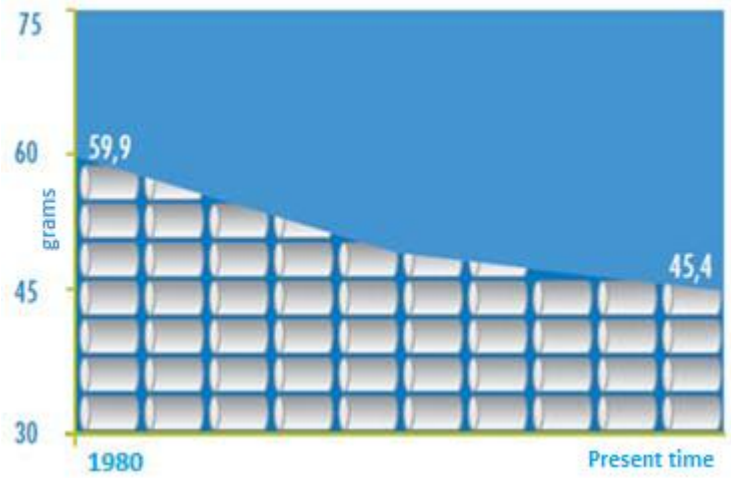

Fig.4 Weight reduction of 425 ml food package in wider time horizon [3]

III. TYPES OF THIN PACKAGING STEEL SHEETS

Thin tinned packing steel sheets are divided based on quality tests. The most widely used tests for typization of steel sheets are Rockwell hardness test and a one-axis tensile test to determine the value of the yield strength and tensile strength. These tests form the basis for the classification of packaging sheets. The Rockwell hardness test is suitable for single-rolled materials (cold rolled, recrystallized annealed and tin-plated). Double-reduction tin-plated steel sheets take the one-axis tensile test. On the basis of these tests, thin sheet steels, simply rolled, are divided into quality groups, so called "tempers" T1 to T5 according to EN 10 203 or T50 to T 65 according to ASTM 623 M-92 and JIS G 3303. The mechanical values for one and two times reduced tin steel sheet according to SEFL and the separation of sheets into tempers are shown in Table 1. [5]

Tab.1 Types of steels and their mechanical properties according to SEFL [5]

	Batch annealing					Continuos annealing				
Temp. EN 10203	T1	T2	T3	T4		T4	T5			
Temp. ASTM, JIS	T50	T52	T57	T61	DR550	T61	T65	DR550	DR620	DR660
HR30Tm	max 50	52 ± 3	57 ± 3	61 ± 3	73 ±3	61 ± 3	65 ± 3	74 ± 3	76 ± 3	77 ± 3
$R_{p\ 0,2}$ *[MPa]*	230	250	280	400	550	400	430	550	620	660
Margin tolerance	±30	±30	±30	±30	±40	±30	±30	±40	±40	±40
$R_{p\ 0,2}/R_m$	65	67	70	70						
Rm [MPa]	330	350	360	400	580	435	450	570	625	665
Margin tolerance	±30	±30	±30	±30	±30	±30	±30	±30	±30	±30

IV. TRENDS IN PRODUCTION

The thin tin steel sheet for the production of metal packaging materials is made of low-carbon deep-drawn, aluminum- deoxidizated steel, cast on a continuous casting machine. At present, two-times reduced materials (DR) are widely used. The resulting product after double reduction has a higher stiffness, hardness, and is stronger than simply reduced. Their use is related to the transition to thinner thicknesses and higher strength of the used sheets. This transition is caused by the permanent pressure of competing materials such as aluminum, glass, paper, PVC and the like. The result is ultra-light tin steel with a sheet metal thickness of 0.14 ÷ 0.19 mm. For the production of beverage cans, the thickness dropped from 0.30 to 0.20 mm, which means that the weight of the can was reduced by up to 40%. This is a significant material saving and a total increase in outputs for the same material consumption. [5, 6]

After the cold rolling process, it is necessary to anneal the material to remove internal stresses and restore the structure, because it is not suitable as packaging material for its properties.
In practice two types of recrystallizing annealing are used, Fig. 5 and Fig. 6:
- BA (Batch Annealing) – annealed in furnaces for softer steels,
- CA (Continuous Annealing) - cold annealing in a continuous manner. [1, 5]

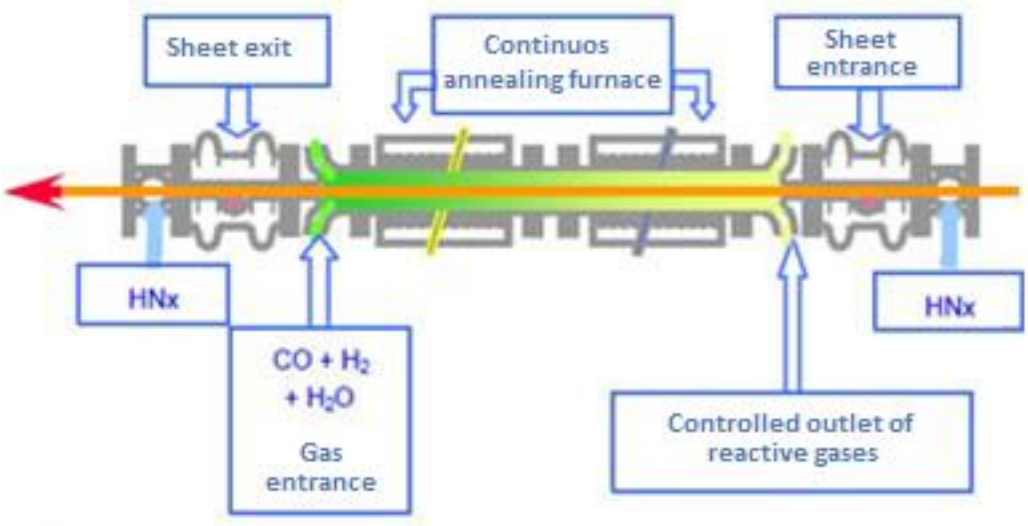

Fig. 5 Continuos annealing furnace

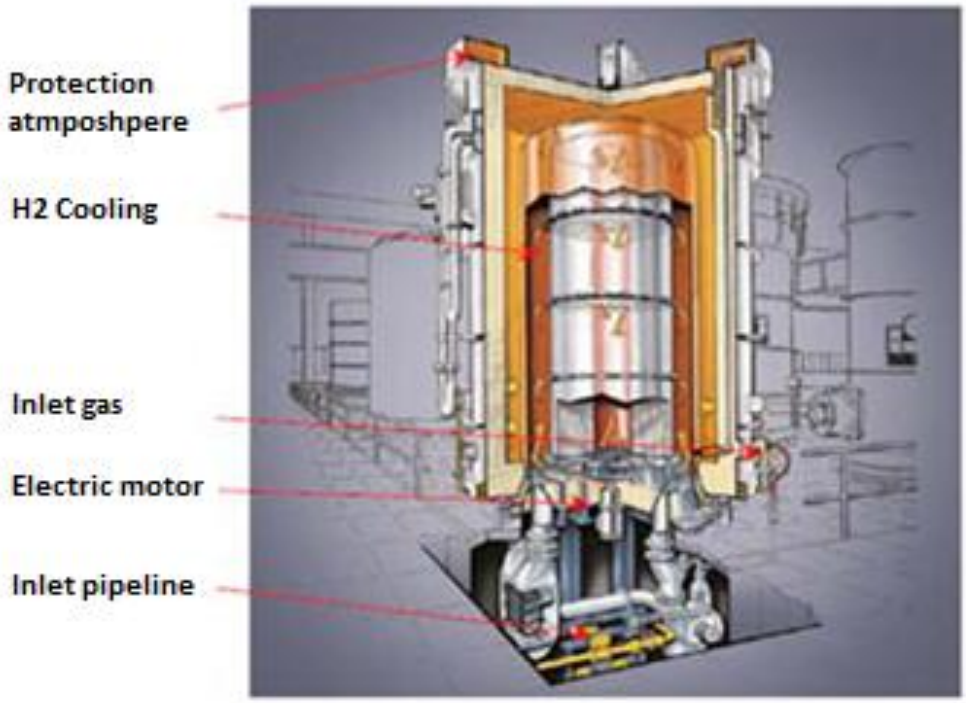

Fig. 6 Batch annealing furnace

The recrystallization annealing process operates in a temperature range of 600 ° C to 800 ° C. It is not always necessary for the heat needed to reach the critical extent to process the steel. Formed steel that is cold rolled several times in the production process is softer at annealing temperature of 500 ° C to 650 ° C for several hours. This process is known as the near-ignition process and is commonly used on wires and sheets. [1, 4, 7]
The recrystallization annealing of the strip is followed by a slight over rolling, on a two-tandem tandem with a 0.5 to 0.8% load, which is also called dry rolling without the use of emulsions. The strip smoothing is performed to improve the sheet's mechanical parameters, to remove minor inequalities from the surface of the strip and to improve the strip profile. This operation is followed by a tensile straightening, which means the belt is extended by a maximum of 2.0% longitudinal pull to remove the belt unevenness. In the case of the production of particularly thin sheets of high strength, the smooth rolling is replaced by another reduction of the thickness by cold rolling in the range of 10 to 36%, i.e. the second reduction. The twice reduced sheet metal is much harder and stronger than the sheet metal that has only been smooth rolled. With this production technology, high yields and strength up to 700 MPa are achieved. Then packaging steel enters an electrolytic tinning line, where the sheet metal strip is tinned on the both sides with the same tin or differential coating (1.0 / 1.1 ÷ 1.4 / 2.0 g / m2). [6,7]

V. CONCLUSION

Packaging steel plays an important role in the packaging industry. Due to its convenient features, besides the food industry, it has an important role to play in the automotive industry as well as in the manufacture of various industrial packages. Trends in recent years, as in the automotive industry, have led to a reduction in their thicknesses and their efficient production while increasing their qualitative properties. Compared to competing materials, their use is a advantage of several benefits, which makes them even more irreplaceable in this area.

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