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D02285

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.73/16
19 October 1970

ENGLISH
Original FRENCH*

Seminar on Tin Plate Production
Santiago, Chile, 9 - 13 November 1970

THE EVOLUTION OF TINPLATE TECHNOLOGY 1/

by the

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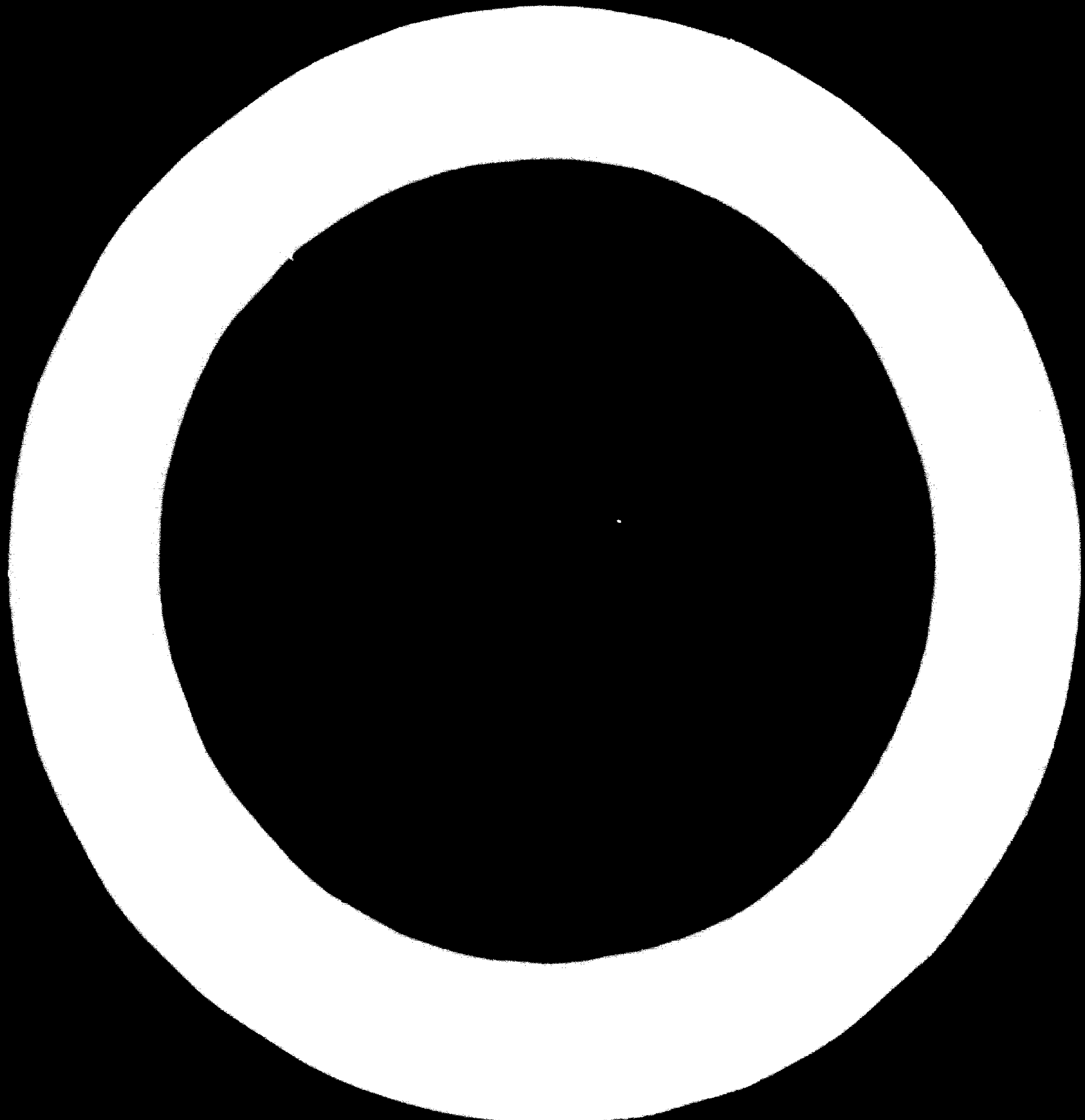
id.70-5764



OCTOBER 1970

THE TECHNICAL EVOLUTION OF TIN PLATE

Tin plate, a basic conventional material in canning, was of such nature as to give many processors the possibility to grow from workshop practice up to the industrial stage. Conventional does in no way mean "antiquated" and tin plate technology has made an extensive headway since the end of the last World war.

Such advancement had a dual purpose : the improvement, on one hand, of production technics and media towards yield increases and subsequent cost lowering, and, on the other hand the simultaneous enhancement of tin plate qualities.

Without delving too much into details, an analysis of this evolution is offered hereunder.

As a reminder is to be remembered that tin plate is a flat product, in cut length or strip form, of soft or extra-soft steel with a coat of commercially pure tin. Within an unexpensive product it combines the mechanical strength and formability of steel with the corrosion resistance, solderability and fine appearance of tin.

Tin plate results from the rolling down of steel into strip to the specified thickness and its subsequent coating with pure tin either by hot-dipping or electrolytic plating.

THE STEEL BASE.

It is the constituent to be described first.

Prior to the last World war steel was exclusively made from the conversion of liquid iron (Basic Bessemer : Thomas steel) or from scrap (Openhearth).

The O.H. process is still responsible for a very important proportion of steel production, but new steel making procedures have been developped since then to directly transform liquid iron into steel, amongst which :

1 - The improved basic Thomas steelmaking process, where through oxygen enrichening of the converter blast it is possible to produce a steel featuring characteristics quite close to those of O.H. steels.

2 - The L.D. (LINZ-DONAU) process, an Austrian development, featuring a down blast through the converter nose inside a stationary vessel.

3 - The LD/AC and O.L.P. processes, developed by the French Iron and Steel Research Institute, wherein the oxygen blast is combined with lime injection and whereby it is possible to extend to the L.D. steel making process the conversion of iron with high phospherous contents.

4 - The Kaldo process, of Swedish origin, to which Sollac in France has extensively contributed and in which the converter is a revolving and tilting vessel with a downward oxygen blast and lime additions through the top.

The process is very adequate for the treatment of liquid iron with high phosphorous contents.

All above steelmaking processes feature remarkably suitable flexibility to permit the conversion of scraps and ores in reasonable proportions. They also make it possible to produce when necessary steels with low nitrogen and phosphorus contents showing excellent deformation aptitude and mechanical properties. With such steels it is possible to simultaneously reach a corrosion resistance capacity, until now only obtainable in O.H. steels. That is the case, for instance, of the "L" steels (P ∠ 0,015 %) and MR steels (P ∠ 0.020 %).

However it also happens that the requirement may call for a metal showing a pronounced rigidity, such as for beer cans or carbonated beverages containers which are to withstand heavy pressures when pasteurized.

This purpose is obtained by adding phosphorous to the steel. It increases the required steel hardness necessary for the lacquered beer cans. In the case of carbonated b e v e r a g e cans, contents of which are more aggressive, the additive is then nitrogen instead of phosphorous; it is a nitriding.

Tapping procedure has also been submitted to some modifications.

Rimming steel heats, in which inclusions segregate heavily upon pouring, are more and more teemed into hot-top moulds yielding a more homogeneous metal and avoiding blisters.

An other procedure towards the elimination of the detrimental incidence of the rimming action consists in contolling the ingot pouring through aluminium additives into the laddle immediately when tapping.

Rimming is then reduced or stopped.

This is how semi-killed or fully killed steels are produced. The operation is none the less costly on account of the important discard to apply as a result of the extensive shrinkage (pipe) produced.

ROLLING OPERATIONS

Black plate was formerly rolled on pack mills, now an obsolete procedure for practical reasons.

Yield was low indeed and phosphorous and silicon additives to the steel to prevent stickers were detrimental toward tinplate adequate resistance to oxidation.

Ingots are to-day rolled down into slabs, the head of which, corresponding to the ingot top, being adequately cropped. They are then scarfed before being finally reheated and hot reduced into a hot strip in thickness ranges ca. 2 millimetres in a tandem hot mill.

Hot rolled strips undergo then a mechanical descaling and an acid pickling prior to being oiled, recoiled and cold-reduced in reversing or five five stand tandem cold mills.

The process, known as "cold rolling" (or cold-reducing), produces in the tin plate gauge range a very flat product in uniform thickness with a smooth appearance.

ANNEALING

This operation aims at dissipating the rolling stresses established subsequently to the cold reduction. It is performed after the elimination, in a cleaning line, of the palm oil left over on the strip after cold reduction.

Most of the time the heat treatment consists in a "box-annealing" which has some short comings in itself : impossibility to apply temperatures above 690° C (1274° F), heterogeneity of recrystallization in the steel between inner and outer sections of the coil and above all the required treatment cycle tying up the product for almost 6 days.

This type of treatment has been somewhat improved by making use of a protective atmosphere, the HNX, so as to prevent any surface oxydation and on the other hand by using annealing bases incorporating an integrated ventilation system to help shorten the cooling cycle.

In a more recent process, the continuous annealing, the strip travels through an annealing furnace incorporating prior to the delivery end a cooling equipment, all of which working within a protective HNX atmosphere. It is possible that way to get a better heat distribution, a faster and more even heat dissipation, than when operating on coils. Superficial hardness also remains the same from strip edge to center area, a performance much more difficult to get with "box annealing".

The continuous annealing permits to reach very quickly up to 700° C (1292° F) which helps the recrystallization and its even progression within the full strip width. In this type of cycle, coil immobilization is considerably shortened.

With such a process it is finally possible to obtain on strips so treated a very high temper, called Universal temper "TU", most generally reaching values up to T.5., without having to resort to a modification of the steel analysis.

SKIN-PASS.

The complex purpose of the skin-passing is dual.

It aims first at restoring a certain hardness to the metal which has lost an important part of it through the annealing. It helps prevent "fluting" when forming the can cylindrical b o d y by restoring uniform deformation when it comes to exceed yield point values.

The second purpose is to impart to the product a surface finish and produce an adequate standard of flatness.

This temper rolling is a sort of dry rolling on a special two stand tandem mill involving an important reel tension control between the two stands.

Strip elongation subsequently to such processing is ca. 1 1/2 % and the strip shows then the required superficial hardness or "temper".

This type of mill generally involves smooth ground rolls in the exit stand, capable of imparting to the strip a bright surface finish.

For certain purposes however these rolls may, instead of being smooth, either be shot blasted or roughened by special grinding in order to impart to the product different surface appearances.

Such surface finishes correspond to definite end-uses.

STONE-FINISH

Tin plate with such a finish shows a microscopical fine scored appearance though remaining still bright. It is possible with that type of roll grinding to give the plates an adequate standard of flatness and its surface is much less sensitive to surface scratches upon can processing.

SILVER FINISH

The rolls are rough ground and it is possible to produce, after the melting of the electrolytic tin deposit, a multitude of tiny bright facets.

It is mainly on account of its ornamental appearance that this type of tin plate is made use of in "de luxe" packing, therefore in limited quantities.

MAT FINISH

For this purpose rolls are ground smoother than for the silver finish and the unmelted electrolytic tin deposit is of a semi-lustrous mat. That type of tin plate does not solder adequately and its end use is therefore mainly for crown bottle cap fabrication.

DOUBLE REDUCTION (DR)

When temper-rolling, it is possible to proceed to an actual rerolling with palm oil to produce a new product called "double reduction" tin plate, which does not require any further skin pass. Plate thickness is then in the ca; 0.15 to 0.17 m/m thickness (.005906" to .006693"). Temper on the other hand remains high, in the Rockwell 30 T superficial hardness range value of 73 ± 3.

With that type of plate it is possible, after modification of the can processing lines, to manufacture containers as strong as those made of the conventional .22 to .24 m/m (.008661" to .009449") thick plates, the reduction in gauge being balanced by the hardness increase.

"DR" is also applied on standard gauges, such as .25 to .27 m/m (.009843" to .01063") affording high strength packing media for industrial products.

It has however the disadvantage of being a "fibrous" material, along the rolling direction, and it therefore requires special arrangments when being processed.

TINNING

The old "hot dip" tinning process, whereby the black plate was immersed in a molted tin bath falls progressively into obsolescence to the profit of the electrolytic tinning which has some advantages :

- Continuous tinning of the steel strip
- Important savings through accurate control of a uniform tin deposit on each side of the plate and consequently decisively lighter than what offers hot dipping for the same type of protection.
- Possibility to differentiate the weight of the tin deposit on each side, an other cost saver.
- Passivation applied at the ultimate stage of the electrolytic tinning, imparting an excellent resistance capacity against oxidation when stored and against sulfuration.
- Eventual production of tin plate in coil form and not exclusively in cutlengths.

There are three types of electrolytic tinning lines :
- The acid horizontal line, or "Halogen" type.
- The acid vertical line, or "Ferrostan" type.
- The alkaline type.

The "Ferrostan" type is the most widely used one in Europe and more particularly so in France.

The "Ferrostan" electrolytic tinning line may be divided into several sections according to the type of operation applied.

- The entry section where the coils are welded together tails to ends in order to ensure a continuous pay-off feed to the successive processing sections :

- The section for the preparation of the surface, where cleaning, pickling, rinsing and brushing are performed.

- The tinning section.

- The finishing section, where melting, passivation and oiling are performed.

- The recoiling or the shearing section.

These types of lines are being perpetually modified in order to improve on the one hand production yields and size capacity, and, on the other hand on account of improvements from research and trials.

It shall not be dwelt extensively on the line entry side, its modifications remaining purely of a general engineeing nature.

Modifications made within the surface preparation section have permitted improvements of surface appearances, whereby it has been possible, amongst other things, to develop "K" type tin plate with the help of HNX gas in the annealing furnaces. The behaviour of this type of tin plate as to corrosion from acid beverages such as grapefruit juice has been notably improved.

The "K" type tin plate must comply satisfactorily with the four following tests :

. "Alloy tin couple" or ATC test, based on the corrosion couple arising from the reaction between tin and the tin-iron alloy. The test consists in measuring the current between a tin electrode and the tin-iron alloy.
. The "Iron Solution Value" or JSV test. It is the amount of iron which dissolves through the tin and tin-iron alloy layer over a determined surface.
. The "Pickle Lag" test consists in measuring the time lag occuring prior to hydrogen emission off a tin plate sample completely stripped of its tin coat, when dipped in an acid solution. Its purpose is to gauge certain surface characteristics of the steel base.
. The "Tin Crystal Size" test, which establishes the sizes of the tin crystals in the tin coat.

Developments applied in the tinning section of the line aim at improving the quality simultaneously with the production yields. Production of tin plate with differentiated tin coat weight on both sides is now standard practice.

The modifications applied to the delivery end of the line these last years have made it possible to improve certain characteristics of the tin plate.

MELTING

The process consists in increasing the temperature of the tin layer by induction heating, by electric resistance, radiated or high frequency heating up to its melting point. Electric resistance and induction heating are applied in certain lines in France, either separately or in combination.

The strip is immediately quenched thereafter by immersion into a water tank where temperature is adequately controlled in proportion with the type of tin coat weight processed.

The operation is to restore superficial brightness to the tin deposit and simultaneously spark off the formation of tin-iron alloy.

It is through the improvements made upon this alloy that "K" type tin plate production has been obtainable, since formerly it was only possible on hot dipped plates on which it was spontaneous.

To restore such an alloy after electrolytic tinning was therefore a necessity on account of its threefold action :

. Improved bonding between the steel base and tin.

. Improvement of the solderability, especially for high speed operation.

. Its very important action towards tin plate corrosion resistance against certain packed products.

It is standard practice to restore tin surface brightness by melting, but, for certain end-uses for which a satin finish is required, the black plate base surface is slightly roughened when rolled and surface tin melting is not applied, it is the mat finish. Without the above base plate preparation and subsequent melting the resulting product is a tin plate with an unmelted coat and showing a different aspect. Finally, with a more accentuated surface roughness (through rolling) the base plate, plus a subsequent tin layer melting, a silver finish is obtained. These different surface appearances have already been mentioned previously.hereabove.

PASSIVATING

This processing, paramount as to what concerns tin plate superficial condition, resistance to oxidation, to corrosion and sulfuration from certain canned products strongly contributes to adequate enamel adherence and lacquer sprinkling capacity, directly influences tin plate behaviour, particularly as to what concerns lacquering and soldering and the warehousing life of the tin cans.

It consists in the creation on the thin layer of a tin and chrome oxide film as much stable as possible at room and baking temperatures.

Such passivation film however must not be too stable in order not to interfere with an adequate soldering.

Passivating is either a purely chemical process which consists in immersing the strip in a chromic acid or chromium bichromate solution followed by a subsequent rinsing and drying, or an electrochemical process.

The second type results from the cathodic reduction in a dichromate solution bath of the oxide layer grown after melting.

Laboratory researches have shown that these two passivating processes create oxide layers of different nature and with different characteristics. Thicker, more porous and less stable under heat in the electrochemical one.

The latter offers a very suitable protection against sulphide discoloration, thanks to the existence of metallic chrome besides the oxides.

OILING

Oiling consists in covering the passivated layer with a thin cottonseed oil or di-octyl sebacate oil film in the proportion of 0.20 grammes per sq. meter of actual area, operation being made by spraying or electrostatic deposit.

The operation must be carefully controlled so that the oil film is of such thickness as to prevent surface scratches during manufacture and oxidation during warehousing, but also in a such thin film as to permit lacquering and printing without the production of thin spots and unlacquered areas.

At this stage, the tin plate strip may either be coiled up or sheared into cutlengths, depending upon the types of manufacturing procedures contemplated.

When manufacturing requires tin plate in cutlength form, it is automatically assorted according to gauges, computed, stacked on pallets after sorting out defective or pinholed plates.

When the manufacturing procedure requires tin plate in coil form, it is possible by using the same sort of gauging and detection equipment to flag out the defective zones which cannot be discarded in the course of the mill operations.

TIN FREE STEEL (TFS)

As a reaction against the high cost of tin and its eventual world shortage, as so often publicized, European mills, and more particularly the French ones, have made researches and developed, these few last years, tin plate with lighter and lighter tin deposits.

They have recently gone some further by acquiring the necessary equipment for the application of different patents they bought, from the Japanese more particularly, relating to the production of tin free steels with the help of a chrome alloying or a chromatizing process, both being finally very similar.

French and European mills are right now in the position to supply this type of product whilst carrying on researches to further improve TFS quality and production, though they are not the originators.

CONCLUSION

As a conclusion to this very sketchy report there is the firm opinion that the extensive developments made until now in tin plate technology, and consequently in its quality, are just one step in its advancement.

As already stressed out previously, research laboratories and can makers in their permanent and close co-operation for the development of tin plate were indeed the advancement factors of the simultaneous growth of the packing industry.

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