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DAINOX BRIGHT[1]

DEVELOPMENT OF AN IMPROVED PROCESS FOR COLD ROLLED STAINLESS STEEL STRIP PRODUCTION (A&PL) WITH HIGH SURFACE QUALITY, LOW PRODUCTION COST AND LOW ENVIRONMENTAL IMPACT

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Abstract

"DaInox Bright™" is trade name given to an innovative process technology that has been developed for annealing and pickling for cold rolled stainless steel strip. The key point of this process, is a dramatic reduction of the oxide layer generation during the annealing, in comparison with the conventional one. As a consequence, chemical pickling treatment is reduced/eliminated, giving and enhanced surface quality and reducing environmental impact.

Key words: Stainless steel; Special steels; Cold rolling mills; Annealing lines; Pickling lines; Processing.

DAINOX BRIGHT
DESENVOLVIMENTO DE MELHORIA NO PROCESSOS DE RECOZIMENTO E DECAPAGEM DE TIRAS LAMINADAS A FRIO PROPORCIONANDO MELHOR QUALIDADE SUPERFICIAL, MENOR CUSTO DE PRODUÇÃO E MENOR IMPACTO AMBIENTAL

Resumo

"DaInox Bright™" é um nome comercial dado a uma inovação de tecnologia desenvolvida nos processos de recozimento e decapagem das tira de aço inox laminadas a frio. O ponto chave deste processo é a dramática redução de geração óxidos durante o processo de recozimento, em comparação com o processo convencional. Como conseqüência o tratamento químico da decapagem é reduzido/eliminado, proporcionando melhora na qualidade de superfície e redução do impacto ambiental.

Palavras-chave: Aço inox; Aços especiais; Laminação a frio; Linhas de recozimento; Linhas de decapagem; Linhas de processo.

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1 INTRODUCTION

At the present time, cold rolled stainless steel strips are supplied from production lines with two standardised surface finishes: 2D (2B after skin pass) cold rolled annealed and pickled or 2R (BA) cold rolled, annealed in reducing atmosphere (H_2/N_2) and skin passed. Due to their mirror proprieties and good appearance, 2R (BA) surface finish products are generally preferred to 2D/B one, which looks dull and not reflective, for the so-called “in sight applications”. 2R surface finish production is made on Bright Annealing vertical plant in which the strip is annealed in a H_2/N_2 gas mixture with a controlled dew-point (lower than -50 °C) able to avoid surface oxidation and consequently chemical pickling is not required. The vertical furnace orientation in BA plant reduces the possibility of BA productivity enhancement presently limited to a maximum of about 20-25 t/h.
2D/B surface finish production is generally made on horizontal high capacity continuous Annealing and Pickling line with productivity up to 150 t/h in which strip is annealed in oxidant atmosphere (O_2 content ranging from 1 up to 9 %) containing furnace combustion gas mixture and then it is electrolitically de-scaled and chemically pickled. From a theoretical point of view, no any technological limitation exists in further capacity expansion on A&P Line in the future.

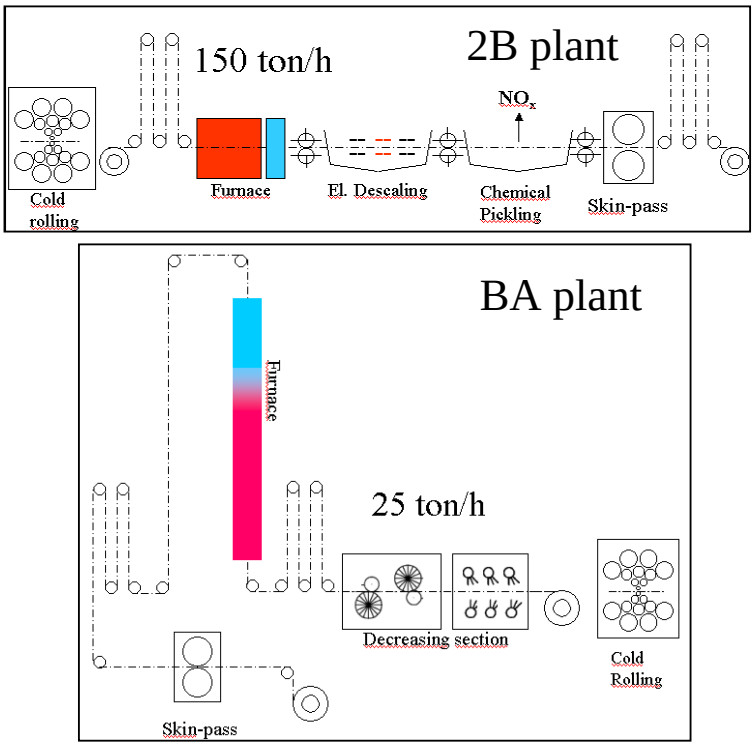

Figure 1: Conventional production schemes of 2B and of 2R stainless steel strip.

The world constant and expected growing consumption of stainless steel products, is driving steel-makers to research new processes and technologies. The main aim is reducing production cost and increasing steel quality and last but not the least decreasing environmental impact of production process .
Pursuing the above mentioned targets, Danieli &C. and Centro Sviluppo Materiali developed a new process and related technologies, able to obtain stainless strip with an high surface quality, with plants having the same production capacity of conventional A&PLs but with low production cost and low environmental impact. The

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established trade name of the new process is DaInox Bright. It allows the elimination (or the reduction) of the environmental impacts of chemical pickling process, lowering the consequent specific amount of polluting substances such as NO_X emissions, nitrates in the disposal water, and sludge.
The key point of this new process is the production of annealed cold rolled strips characterised by a very thin oxide film, with improved proprieties (thickness, composition, morphology) quite unlike from those exhibited by oxide grown up during conventional annealing process, that can be easily removed during pickling process.
The control of the formation of above mentioned oxide film is achieved utilising specific strip thermal cycles and different atmosphere composition at each processing step (heating and cooling).
During the initial rapid heating stage of the conventional continuous annealing processes, a thin oxide layer very rich in Chromium is generated. Such a layer acts as a diffusion barrier limiting, for very short time, the further oxidation of Fe. In DaInox Bright process, a very thin oxide film, is not further increased in thickness at the highest temperatures and during cooling step. This is reached utilising a non oxidising atmosphere.
This paper reports the first results of the experimentation performed on the austenitic stainless steel grade (AISI 304). Similar results have been obtained for the thermal treatment of ferritic stainless steel strip.

2 METHODS AND MATERIALS

2.1 Experimental Method

2.1.1 Materials

The annealing trials have been performed on 1 mm thick cold rolled AISI 304 austenitic stainless steel mini-coils (width 300 mm; length 600 m) previously degreased and characterised by a surface roughness (Ra) ranging between 0.05 □m and 0.07 □m.

2.1.2 Continuous Annealing Pilot Line

The annealing pilot line installed in DANIELI R&D is able to treat continuously strips 0,4-2 mm thick at a process speed up to 10 m/min. It is built up with refractory materials that allow to realise a wide variety of strip thermal cycles under different atmosphere compositions (oxidising and inert) at each process steps (heating and cooling). In Figure 2 the picture of the annealing pilot line is shown.

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Figure 2: Picture of Danieli Pilot plant.

2.2 Experimental Annealing Trials

The experimental campaign has been devoted to define the annealing process conditions in terms of heating rate and atmosphere composition at low and high temperatures to obtain an oxide film with the mentioned properties.
Conventional annealing cycles has been performed on cold rolled strip to get samples of industrial production as reference.
The pickling tests (electrolytic and acid) working in the same conditions of the continuous industrial plant have been performed in batch by CSM (our partner in the development of Dainox Bright process and plant).
Surface analysis was performed by GDOES and by SEM techniques giving information on the oxide film thickness, composition and morphology.

3 RESULTS AND DISCUSSION

According to the new DaInox Bright process the heating cycle is divides in two main parts:

- The first part, where the strip is at low temperatures, takes place in the direct flame oxidation furnace. It allow the heating of the strip up to 850-950 °C (for the austenitic stainless steel). The control of the Cr oxides nucleation and the generation of a thin layer of oxide film happen by the control of the heating rate and O_2 free concentration.
- The second part, where the strip reaches the maximum temperature (up to 1100°C), takes place in a furnace that perform indirect heating of the strip, by radiant tubes or electrical resistance. The atmosphere in this zone is no-oxidising thanks to the continuous feeding of nitrogen. Also the cooling of strip is realised under the same atmosphere. The wide campaign of experimental test demonstrated that inlet of low flow rate of air (during the operation of the change of the rolls) doesn't provoke any further oxidation of the strip. The key point is to avoid, by the pressure control, the inlet of the combustion gases in the non-oxidising zone of the furnace.

In Figure 3 the oxide film thickness evaluated by GDOES depth profiles, of the annealed strips (DaInox Bright) vs standard 2B is reported. The thickness of the oxide layer on the strip treated according with Dainox Bright process is in average 50% lower than the conventional 2B scale.

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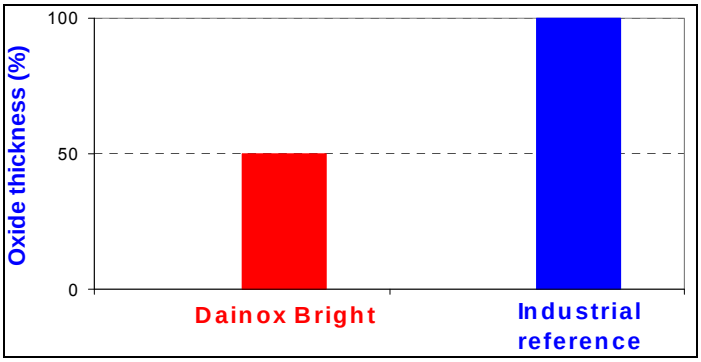

Figure 3. Comparison between Dainox Bright and conventional oxide thickness on the annealed strip

3.1 Descaling Tests and Surface Quality Evaluation

Thanks to the thin layer of oxide generated it has been possible to set-up a new electrolytic descaling process, able to totally remove the oxide, without damaging the mirror characteristics of the strip. The procedure of electrolytic descaling are always applicable in the conventional A&PLs, in terms of electric current density (A/dm^2) and electric charge (C/dm^2).
In the case of high thickness strip it is necessary to apply also a light chemical pickling that is in every case more environmental friendly than the conventional one.
In Table 1 is reported respectively, the values of the reflectivity obtained for Dainox Bright product (austenitic and ferritic grades) in comparison to those obtained for both 2B and BA products.

Table 1: Reflectivity comparison

REFLECTIVITY (% reflected light by an angle of 60°)	**With A&PL**	**Reached values**	**With BA plants**
	2B	**Dainox Bright**	**BA**
AISI 3XX	15 - 22	**35 – 45 ⇒50**	51 – 57
AISI 4XX	36 - 42	**42 - 46 ⇒ 50**	48 – 55

3.2 Scaling Up of the Plant

The process/technology Dainox Bright has no productivity limitations. Dainox Bright A&PL can been designed for the desired productivity as for conventional A&PL. Dainox Bright A&PLs are able to work both as conventional line and for Dainox Bright process.
It has been performed a cost analysis based on European energy and material market prices taking into account the following positions:

- Energy (fuel gas) and process gases consumptions in the annealing section;
- Electrical energy and chemicals consumptions in both the electrolytic and chemical pickling sections (ecological processes);
- Neutralization and disposal of waste solutions and fumes;
- Human resources directly involved on plant operations;
- Metal loss (yield) due to annealing and pickling treatment;

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The cost of Dainox Bright treatment is roughly 35% lower than the conventional A&PL treatment.
The Dainox Bright process could be applicable for:

- Existing plants, by the furnace replacing. The advantages are: increasing of the productivity (more than 30%) and drastic lowering of the pickling and waste materials treatment.
- For new plant, (rougly same investment costs), with advantages in the cost of strip treatment and positive effects in terms of environmental protection.

4 CONCLUSION

The described process regards the annealing of stainless steel strip after cold rolling. The new process allows obtaining both 2B and nearing BA finishing quality with a lower cost of production than the conventional processes for 2B and BA products, and with advantages in lower environmental impact.