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RECENT EXPERIENCES WITH UNS N08031 PLUS ROLL BOND CLADDING

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ABSTRACT

Alloy UNS N08031 Plus (official UNS number under application) was developed very recently to create a material of the same corrosion behaviour as the conventional Alloy UNS N08031 but with improved fabrication characteristics to facilitate manufacturing of large components as much as in hot roll cladding as in shaping and heat treating of large dished vessel heads. The requirement of improved manufacturing characteristics was met by an increase of the nickel content from 31 to 34 % supported by a careful balanced addition of nitrogen and manganese. The new alloy UNS N08031 Plus can be solution annealed at lower temperatures between 1140 and 1160 °C and can be technically hot roll bonded using conventional methods and equipment.

Therefore, the new material can combine the high corrosion resistance of a high-chromium alloyed 6 % molybdenum steel with the cost reduction that can be achieved by roll bond cladding.

The paper describes in short the various production routes that can be used successfully for hot roll bond cladding of alloy UNS N08031 Plus on carbon steel and considers the resulting microstructure, corrosion behaviour and weldability.

Keywords: alloy UNS N08031 Plus, roll bond cladding, microstructure, corrosion behaviour, weldability

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INTRODUCTION

Alloy UNS N08031 is combining the advantages of high-chromium alloyed materials, that is the high resistance to corrosive attack by oxidizing media, with a molybdenum content of more than 6%. The nickel content is comparatively low. This way it was possible to create the highly corrosion resistant material UNS N08031 in using only small amounts of expensive alloying elements [1].

Alloy UNS N08031 shows good resistance to pitting and crevice corrosion in neutral and acid aqueous solutions, which makes it advantageous over the known 6 % Mo stainless steels and even several nickel alloys. Therefore, it lends itself to applications as e.g. flue gas desulfurization, concentrating of diluted sulfuric acid, pulp & paper, phosphoric acid, acetic acid, salt brines and hot seawater as a promising material for a multitude of applications. Alloy UNS N08031 is readily weldable without risk of intercrystalline corrosion.

The successful and widespread use of alloy UNS N08031 resulted in the need to make it easier to handle since the original alloy is requiring a solution annealing treatment at about 1180 °C followed by fast cooling that is not so easy to perform in every place of manufacturing. This requirement was met by a recent adaptation of alloy composition resulting in an alloy UNS N08031 Plus [1]. The alloy UNS N08031 Plus can be solution annealed at lower temperatures between 1140 and 1160 °C, which is much more convenient in manufacturing. This was achieved by means of a carefully balanced composition with increased nickel content to approximately 34% and optimized additions of nitrogen and manganese.

The nominal composition of this alloy is shown in **Table 1** in comparison with the precursor alloy UNS N08031. The alloy modification facilitates manufacturing of large components in particular in roll bond cladding as in shaping and heat treating of large dished vessel heads.

Table 1
Nominal composition of alloy UNS N08031 Plus in comparison alloy UNS N08031

	Ni	Cr	Fe	Mo	Mn	Cu	N
UNS N08031 Plus	34	27	bal.	6.5	2	1.2	0.2
UNS N08031	31	27	bal.	6.5	1.5	1.2	0.2

METHODS OF ROLL BOND CLADDING

A complete description of the production methods by which roll bond cladding can be done has been published recently [2]. Generally, in roll bond cladding the unalloyed or low-alloy base material and the high-alloy cladding material are metallurgically bonded under the effect of the pressure and the temperature involved in the rolling process. The plate achieves its final dimension during this process. The starting product is a pack consisting of the individual materials. The dimensions of the pack, and thus of the materials used, depend on the finished size of the clad plate and on the weight and size which the heating furnace and the rolling stand can handle [2].

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For a reliable bond between the materials, the formation of passivation layers and scale during preheating must be prevented and the absence of adhering dirt particles or other contamination in the later bonding plane must be ensured. Absolute cleanness is therefore essential when assembling the packs. In addition, oxygen ingress and thus the renewed formation of a scale or passivation layer must be excluded [2].

Where production route related size and weight limits allow, a symmetrical pack is assembled which is separated into two distinct clad plates after bonding. As illustrated in **Fig. 1**, in such a sandwich pack, the base material plates are on the outside and the two cladding sheets on the inside. A separating agent is applied between the two cladding sheets to prevent their fusing together [2].

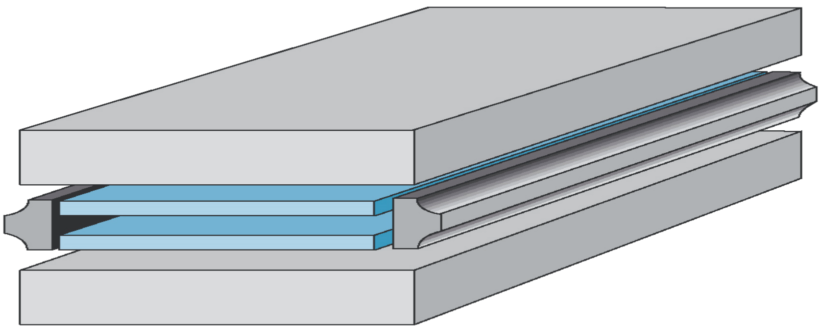

Fig. 1: Schematic illustration of a symmetrical sandwich pack [2]. The two base materials on the outer sides cover the cladding materials between them. An anti-stick agent prevents fusion between the two cladding layers. A welded frame provides for air-tight sealing of the pack. The subsequent rolling process produces two clad plates from the sandwich pack.

This paper reports on alloy UNS N08031 Plus as cladding material. Generally, cladding materials mostly serve as corrosion protection or are selected according to their corrosion behavior and ability to handle aggressive media. The mechanical loads acting on clad plates are usually carried entirely by the base materials which are e.g. structural steels and pressure vessel steels [2]. Base materials are not considered specifically in this paper but are of importance in the background since every kind of hot forming and heat treatment of the clad compound must fit to the requirements of both the cladding and of the base material.

For roll bond cladding of alloy UNS N08031 Plus on carbon steel base materials essentially two methods are possible that allow the specific requirements of bonding and corrosion resistance to be met:

- without heat treatment (quenching and tempering):
roll bond cladding is integrated into the hot rolling operation at elevated temperatures and with subsequent accelerated cooling without final heat treatment,

- including a heat treatment (quenching and tempering):
roll bond cladding is achieved in various hot rolling operations with subsequent hardening with quenching in water, followed by a tempering treatment with final cooling down in air as required by the base material to adjust its mechanical properties.

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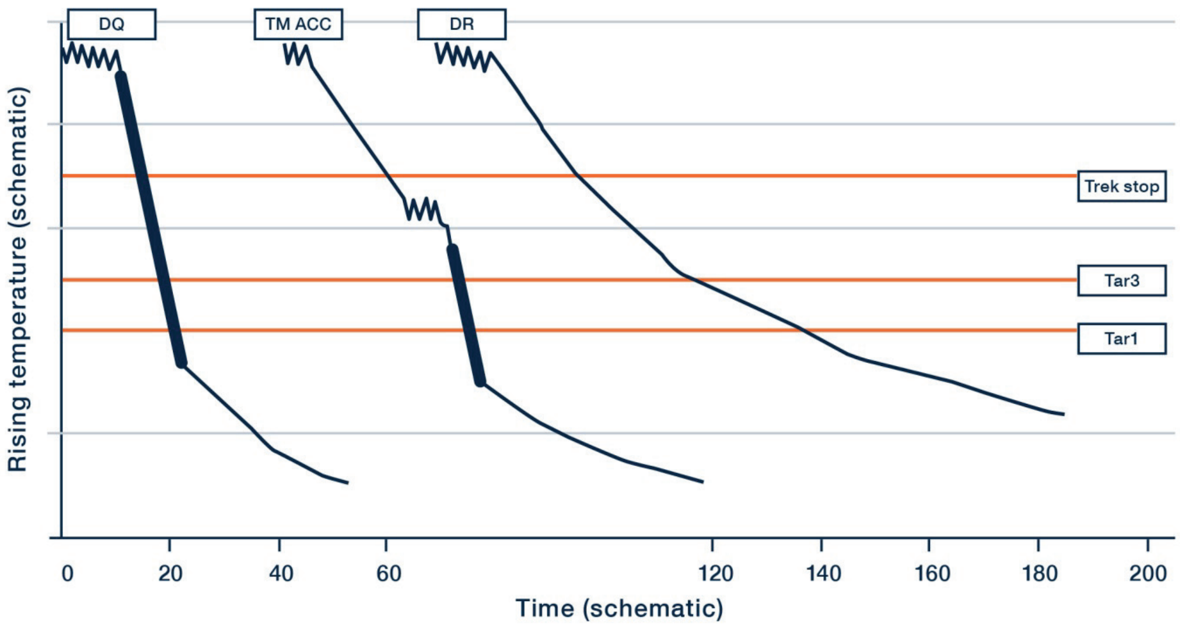

Fig. 2: Production routes in hot roll bond cladding of plates.

Fig. 2 shows schematically how the temperatures of the materials which are to be roll bond clad are a function of time when the different production routes DQ (direct quenching), thermo-mechanical rolling with subsequent accelerated cooling (TM ACC) and rolling to shape or direct rolling (DR) come into play. The serrated lines in the top position and below stand for shaping by hot rolling, the thin lines stand for cooling in air, and the thick lines symbolize an accelerated cooling with water. The horizontal orange lines indicate the end of recrystallization of the base material (Trek stop), the start of phase transformation in the base material (Tar3) and the end of phase transformation in the base material (Tar1).

The production route DQ is to be considered as a way to pass the high temperature area very fast immediately after hot rolling has been completed in order to avoid sigma phase formation in the corrosion resistant clad layer. Within the production route DQ, the accelerated cooling process maybe interrupted at a certain temperature, so that the remaining heat from the interior of the plate gives a tempering effect to the base-material; whereas in a traditional heat treatment Q+T the cooling process is not interrupted, so that after the quenching a separate treatment-step “tempering” must follow.

If the materials which are to be roll bond clad allow, the thermo-mechanical rolling with subsequent accelerated cooling (TM ACC) is the preferred production route.

In case of alloy UNS N08031 Plus also direct rolling (DR) with a suitable final thermal heat treatment is possible.

Alloy UNS N08031 Plus can be roll bond clad without any problems, as much as on the production route DQ (rolling to shape or direct quenching) as on the production route TM ACC (thermo-mechanical rolling with subsequent accelerated cooling).

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MICROSTRUCTURE AFTER ROLL BOND CLADDING

A multitude of microstructural investigations has been performed on alloy UNS N08031 Plus after roll bond cladding on a carbon steel substrate. **Fig. 3** shows the microstructure of such a sample taken from a roll bond clad plate 22.8 mm (base clad steel) + 3.4 mm (clad layer), manufactured according to the production route DQ (direct quenching DQ in Fig. 2). The microstructure is homogeneous, without any precipitates of sigma phase at the grain boundaries. The same material after an additional heat treatment at 1160 °C/followed by a water quench plus annealing at 580 °C/followed by cooling down in air looks homogeneous as well, only the grain structure has become coarser (**Fig. 4**).

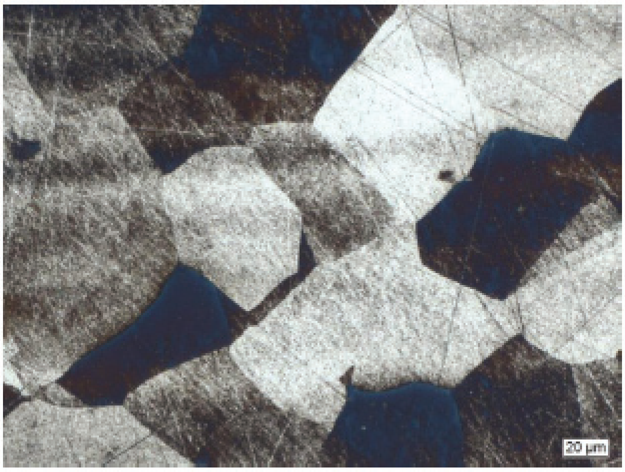

Fig. 3: Microstructure of an alloy UNS N08031 Plus sample taken from a roll bond clad plate 22.8 + 3.4 mm, manufactured according to the production route DQ (direct quenching in Fig. 2).

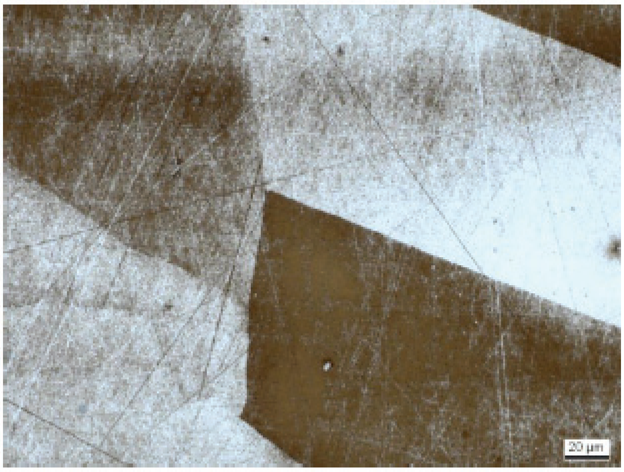

Fig. 4: Microstructure of an alloy UNS N08031 Plus sample taken from a roll bond clad plate 22.8 + 3.4 mm, manufactured according to the production route DQ (direct quenching in Fig. 2) after an additional heat treatment at 1160 °C/followed by a water quench plus annealing at 580 °C/followed by cooling down in air.

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ROLL BOND CLADDING IN CORROSION TESTING

A number of samples which had been roll bond clad with alloy UNS N08031 Plus had been tested on intercrystalline corrosion according to ASTM G 28, Method A - Ferric Sulfate-Sulfuric Acid Test [3]. Since the alloy UNS N08831 Plus is not yet mentioned in the standard both ASTM G 28 standard durations of testing time 24 hrs and 120 hrs have been tried. Testing of Alloy UNS N08031 Plus cladding resulted in corrosion rates of < 0.25 mm/a of the clad layer, very low related to the specific conditions of this test, and close to the value as observed on alloy UNS N06625, as one would expect from the relation of alloy constituents chromium and molybdenum [4].

WELDING OF UNS N08031 PLUS ROLL BOND CLADDING

Joining of roll bond clad plates is usually done by welding. In case of low total thickness only one sufficiently high alloyed filler metal is used to weld both the base material and the cladding. In case of alloy UNS N08031 Plus the recommended filler metal is AWS ERNiCrMo-13, based on alloy UNS N06059. **Fig.5** shows a series of UNS N08031 Plus roll bond clad samples without and with ERNiCrMo-13 weldments.

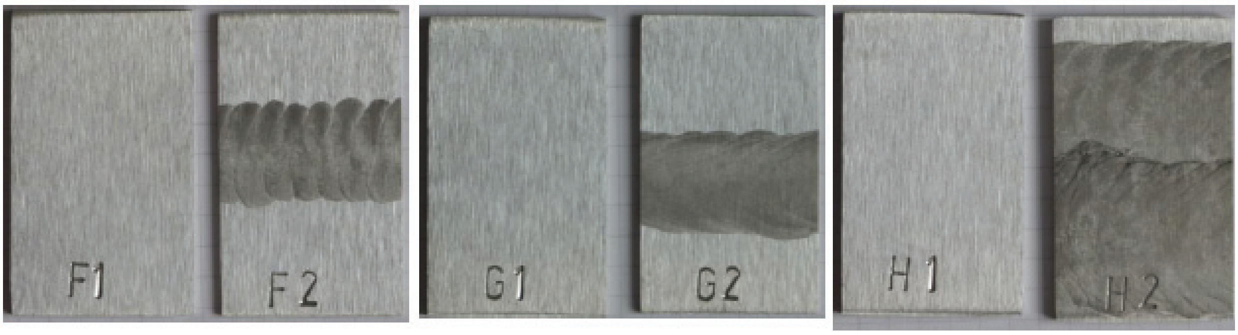

Fig. 5: Series of alloy UNS N08031 Plus roll bond clad samples without and with an ERNiCrMo-13 weldment.

Corrosion testing of ERNiCrMo-13 welded roll bond clad combinations of carbon steel + alloy UNS N08031 of thickness relations 6.9+2.4 and 22.8+3.4 in boiling 50 % H_2SO_4 + 42 g/l $Fe_2(SO_4)_3$ ASTM G-28 A test solution resulted in a corrosion loss as to be expected when alloy UNS N06059 is tested as cladding layer.

When testing the resistance to pitting corrosion, using the method according to ASTM G 48 A [5] for 72 hrs at 50 °C, neither an increased corrosion loss nor pitting was observed at and around the weldments. Also when performing this test at 70°C neither pitting in the weldment nor in the heat affected zone has been observed.

No intercrystalline corrosion has been observed on alloy UNS N08031 Plus weldments so far.

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NEW APPLICATIONS WITH UNS N08031 PLUS

The high degree of versatility offered by the high resistance to corrosion in a multitude of different media allows some unique applications of alloy UNS N08031 Plus. **Fig. 6** shows an example of application as a material of construction for evaporators in the salt industry.

Fig. 6: Example of application of alloy UNS N08031 Plus for evaporators in the salt industry. Equipment manufactured by ZIEMEX.

CONCLUSIONS

1) For roll bond cladding of alloy UNS N08031 Plus on carbon steel essentially two methods are available that allow to meet the specific requirements on bonding and corrosion resistance: a) without tempering: roll bond cladding is integrated into the hot rolling operation with subsequent accelerated cooling; b) including a tempering treatment: roll bond cladding is achieved in various rolling operations followed by a tempering treatment as required by the base material to adjust its mechanical properties.

2) The alloy UNS N08031 Plus can be roll bond clad without any problems, either on the production route DQ (rolling to shape or direct quenching) or on the production route TM ACC (thermo-mechanical rolling with subsequent accelerated cooling).

3) With suitable production methods the microstructure of the alloy UNS N08031 cladding is homogeneous, without precipitates of sigma phase at the grain boundaries.

4) Corrosion testing of an alloy UNS N08031 roll bond cladding in a Ferric Sulfate - Sulfuric Acid - Solution according to ASTM G 28 A resulted in very low corrosion rates of the clad layer. No signs of intercrystalline corrosion were observed.

5) Corrosion testing of welded roll bond clad combinations in the same test solution with AWS ERNiCrMo-13 as filler metal resulted in a corrosion loss as to be expected when alloy UNS N06059 is tested as cladding layer.

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