Dillinger Offshore Letter

PRESSURE VESSEL- AND BOILER P

Crude oil and natural gas are basic sources for energy production and for thousands of petrochemical, chemical or pharmaceutical products. For the hydrocarbon processing industry in particular a wide variety of pressure vessel types is needed. Immediately after passing the drill hole, oil and gas come in contact with the initial pressure vessels such as separators.

Not only pressure but a number of other important parameters (medium, temperature, thermocycling,...) have to be considered in order to design the most suitable pressure vessel with the proper steel material. Moreover safety, performance and efficiency of a plant are of major importance. Consequently, it is in the interest of all those concerned to work closely together to find the best solutions.

Dillinger Hütte GTS has now made a name for themselves in the world of plate manufacturers for boilers and pressure vessels (see production program in the table). In this issue and in those following, we will give you an idea of why we have such a good position on the market and detailed reports highlighting some of our possibilities.

Dr. G. Luxenburger (Marketing)

DICREST: HIC-resistant pressure vessel plates - Production route and quality control

Cracking, due to hydrogen uptake, has become a major problem for the transportation and handling of H_2S bearing media (i.e. in pipelines and pressure vessels), since this phenomenom impairs both the safety and efficiency of installations. Accidents like the one caused by HIC (Hydrogen Induced Cracking) in Chicago in 1984 resulting in 17 deaths have given rise to much more stringent safety regulations.

As a result of numerous inspection programs and intensive studies, most specifications require HIC testing as defined by NACE standard TM 0284 using the test solution defined in this standard (pH = 5) or increasingly by using the test solution according to NACE Standard TM 0177 (pH = 3) for qualification of the material.

These requirements have challenged the steel producers to investigate the influencing factors on HIC crack initiation and propagation and to take this knowledge as a base for production design.

The key to getting stable and reproducible HIC-resistance, not only in the tested sample, but throughout the whole order is:

- the performance of a specifically optimized production route (requiring special facilities) and
- the application of a specifically adapted quality control system.

Optimized Production:

Table 1 gives some measures of the production process route applied in order to achieve the defined HIC-resistance:

- Hot metal desulphurization,
- Converter treatment (low P- content),
- vacuum tank degassing (low S-content),
- cleanliness stirring,
- Ca-treatment (inclusion shape control),
- optimized casting conditions,
- high shape factor rolling,...

+ Optimization of the whole production process route (incl. pouring technique, choice of the slab size, rolling technique,...)

Table 1: Some parts of the production process for new sour service steels

It is worth mentioning that prescribing composition ranges and some special production steps itself is not sufficient and does not say anything about the real HIC resistance of the material. For instance, achieving a low S content is necessary but not sufficient (s. Fig. 1). Performing a vacuum treatment is not the decisive point, but this treatment itself should be optimized for HIC resistant steels. It is the same for the Ca-treatment: the amount and manner of the addition of Ca must be defined taking into account the low S-content for HIC-resistant

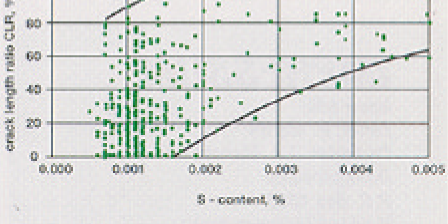


Fig. 1: Conclusion: limitation of analysis is not enough in order to get low CLR-values

200000 t boiler and pressure vessel plates in 1994

- Unalloyed and alloyed steels (acc. to international specifications and engineering standards)
- Sophisticated steels for special applications:
  - CrMo alloyed plates with step cooling requirements for reactors ,
  - DICREST: HIC resistant pressure vessel grades,
  - DIWA: high strength steam drum steels,
  - high strength quenched & tempered pressure vessel steels,
  - Thermomechanically rolled steels (e.g. for LPG-storage),
  - steels for enamelled pressure vessels.
- Great dimensional possibilities: e.g. Max. width: 5.2 m, plate over 250 mm in thickness and 36 mt unit weight.
- Heavy fabrication shop to support our customers (particularly for larger fabricated parts):
  - heads (up to 4.5 m diameter without weld seam),
  - heavy wall cylindrical shells,
  - pressings,
  - spherical shell plates,
  - cut to shape plates.

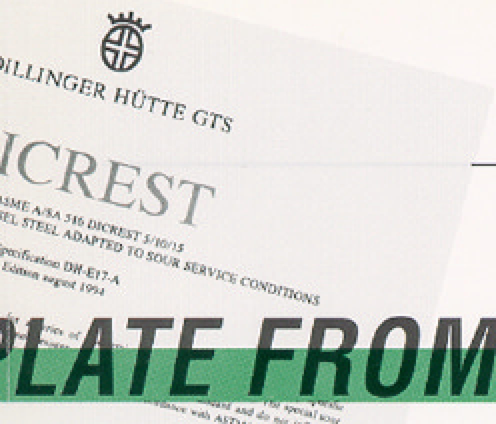


PLATE FROM DILLINGER HÜTTE GTS

steels (typically S < 10 ppm). In such cases however the Ca/S ratio itself is not the decisive parameter. Another example is the casting process: an extremely careful casting technique is implemented for HIC resistant steel like DICREST to minimize segregation. Moreover, it seems advantageous to have, like Dillinger Hütte, a vertical bending continuous casting machine with bending only after complete solidification in order to have less non-metallic inclusions and to produce the highest classes of HIC-resistant steels

The plate manufacturing process strongly depends on the application of the steel plates: plates for pipelines are preferably produced by TMCP (Thermo-Mechanical Control Process), whereas plates for pressure vessels are mostly normalized. In the last case, an additional heat treatment such as PWHT improves considerably the HIC resistance. Q+T (Quenching and Tempering) process can be performed alternatively to certain types of HIC-resistant normalized or TMCP treated plates. Concerning the rolling technique itself, our big 4-High roll stands enable a High Shape Factor, i.e a high local deformation in slab core thus achieving an extremely homogeneous and fine-grained microstructure, providing a positive effect on toughness, through-thickness direction properties and HIC-resistance.

Adapted quality control system:

As mentioned, HIC resistance properties are a result of the performance of all production steps with well defined and optimized tolerances.

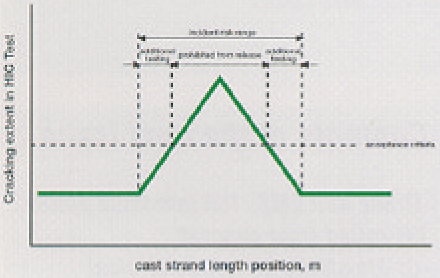


Fig. 2: Aspects of quality assurance system Example of deviation in casting parameter combination

However, during production certain deviations or incidents may occur that directly influence HIC properties while having no influence or minimal impact on other properties. For that reason a special adapted quality control system for HIC resistant steel must be installed. This system should be able to show a deviation of actual process values and to decide if such plates must be prohibited from release and delivery or whether they must undergo additional testing to prove conformity with specification. Fig. 2 illustrates these aspects of quality assurance in case of a deviation in casting parameters.

Typical HIC test results:

Fig. 3 shows that only with an optimized production route and the application of a specially adaptated quality assurance system can a satisfactory and homogeneous HIC resistance be achieved. Therefore it is important for us to specifically know if the steel plates will be applied for a sour service pressure vessel. If not, there is the risk of using so-called "Pseudo-HIC plates" which are not intentionally ordered for HIC applications and therefore are not systematically produced as HIC resistant. These pseudo-HIC steels can, on certain small test pieces, obtain sufficient HIC-test results. However, while an external laboratory certifies the required HIC test results on that particular test coupon, other parts of the plates or cast bear the risk of non-sufficient HIC resistance. Thus, there is an important missing process control which is only applied in case of specified HIC-resistance.

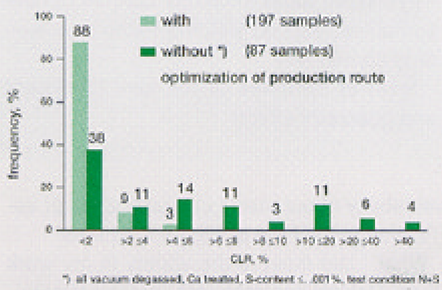
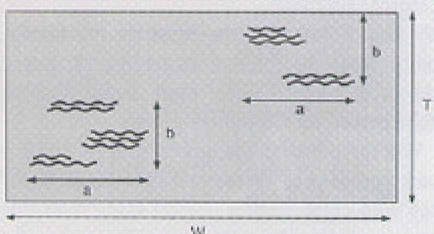


Fig. 3: Optimization of CLR-values in NACE TM 0177-solution through application of special DICREST-production route (steel grades: A 516 Gr. 60, 65, and 70, plate thickness 6-80 mm)

DICREST steel qualities:

The special sour gas properties of DICREST pressure vessel steels are in addition to the other physical properties guaranteed in the specified material standard. Dillinger Hütte GTS can supply you with DICREST to meet common standards like ASTM/ASME A/SA 516 (Grades 60, 65. and 70) and EN 10028 part 3 (Grades P275 and P355) - s. specification data sheets DH-E17-A and DH-E18-A. If necessary, we can supply you with tailor-made DICREST based on your own specifications. Table 2 gives you the acceptance criteria in HIC-test for the different DICREST quality levels.

	max. thickness	Test solution	Acceptance criteria		
			CLR	CTR	CSR
DICREST 5	3 in 80 mm	NACE TMO 177 pH 3	≤ 5	≤ 1,5	≤ 0,5
DICREST 10	3 in 80 mm	NACE TMO 177 pH 3	≤ 10	≤ 3	≤ 1
DICREST 15*	6 in 150 mm	NACE TMO 177 pH 3	≤ 15	≤ 5	≤ 2
		NACE TMO 284 pH 5	**) ≤ 0,5	**) ≤ 0,1	**) ≤ 0,05



$$CSR = \frac{\Sigma(a \cdot b)}{W \cdot T} \cdot 100\,\%$$

$$CLR = \frac{\Sigma a}{W} \cdot 100\,\%$$

$$CTR = \frac{\Sigma b}{T} \cdot 100\,\%$$

a = crack length
b = crack thickness
W = section width
T = specimen thickness

*) When ordering DICREST 15, please indicate the preferred test solution.
**) Values of "0" are routinely achieved in the test.

Table 2

References:

- Information brochure DICREST,
- DICREST specification sheets DH-E17-A and DH-E18-A (available on request, please use attached form)

Dr. A. Streißelberger & V. Schwinn
(Research & development)