گزارش تحقیق و تست از نازل مشعل های کوره آنیلینگ خط گالوانیزه

الف – شرح وضعیت موجود و مشکلات ایجاد شده :

در این کوره ۱۵۶ مشعل وجود دارد که ۷۸ عدد در یک طرف و ۷۸ عدد در طرف دیگر قرار دارد.

مشعل ها داخل رادیان تیوب قرار می گیرند و حدود $950^{o}C$ حرارت تولید می گردد. دمایی که سرمشعل ها وجود دارد قابل اندازه گیری نیست ولی دمای خروجی که حاصل از گاز احتراقی می باشد بین 300 تا 500 درجه سانتی گراد است.

فشار گاز مشعل بین ۱۴ تا ۱۸ میلی بار می باشد.

البته شرایط برای هر مشــعل متفاوت است، مثلاً مشعل های ابتدای ورودی کوره دمای بیشتری را تولید می کند و این مشعل ها بصورت اتوماتیک Start یا Stop می شوند.

شرایط کاری مشعل باید طوری باشد که CO در حدود صفر، O_2 در حدود ۲ تا ۴ درصد و CO_2 حدود ۱۰ درصد باشد، بنابراین اگر شرایط کاری بطور دقیق رعایت شود وضعیت شعله نباید اکسید کننده شدید باشد. خنک کردن سیستم از طریق اگزوز فن (مکش خروجی) صورت می گیرد. مشعل ها حالت مابین ندارند یا روشن هستند یا خاموش.

مشـعل هایی که اصـلی هستند (قطعات خارجی) مابین ۲ تا ۴ سال عـمر می کنند و پس از آن در هـنگامی که فرسوده می شوند دفرمه می شوند و این دفرمه شدن از چشمی انتهای مشعل قابل مشاهده است که نشان می دهد شعله متمرکز نیست.

چشمی برای کنترل کردن شعله مشعل

رادیان تیوب هایی که مشعل ها درون آنها قرار میگیرند

مشعـل هایی که ساخت داخل هستنـد بین ۱ تا ۵ ماه عمر می کنند و پس از آن، سـرنازل ها با خـرابی شـدیدی مواجه می شوند که این تخریب هم از کنار روزنه های سرمشعل صورت می گیرد، هم از مقطع جوش داده شده به بدنه نازل، که باعث می شود شعله از قسمت های مختلفی خارج شود و باعث تخریب رادیان تیوب های گران قیمت کوره شود و ممکن است ضربه بزرگی به کل کوره وارد کند. به علاوه زمان Shut Down و تعمیرات جایگزینی ضرر هنگفتی به پروسه تولید وارد کرده است. ساخت این نازل ها بصورتی است که فقط سر نازل ساخته می شود و بدنه آن از قطعه تخریب

شده قبلی تهیه می شود (قطعه خارجی) و قطعه ساخته شده به بدنه جوش می شود که یکی از مشکلات این نازل ها همین جوش این قسمت می باشد.

	
بدنه های خارجی که سر نازل آنها تخریب شده اند	سر نازل جوش داده شده به بدنه خارجی

جنس این رادیان تیوب ها Inconel 601(D) می باشد که تا کنون خرابی های زیادی داشته است و این خرابی ها فقط بوسیله جوش و Sleeve گذاری تعمیر شده است.

Radian Tube		
	ترکی که بر اثر انحراف شعله بر رادیان تیوب ایجاد شده	رادیان تیوب تعمیر شده بوسیله Sleeve

بر اثر باز شدن جوش سرنازل ها تاکنون ۲ بار خرابی کوره مشاهده شده است.

چک کردن سرمشعل ها در قطعات خارجی امکان پذیر می باشد ولی در قطعات ایرانی به علت تخریب زودهنگام، فاقد این مزیت است. نمونه خارجی یک بار در هفته جهت سنجش انحراف شعله چک می شوند که در نمونه ایرانی بخاطر احتمال بالای خرابی، این کار روزانه صورت می پذیرد.

هم اکنون بیش از ۲۰ عدد مشعل خراب در حال کار کردن در کوره هستند.

ب – متد انجام تحقیقات برای پی بردن به دلایل تخریب :

۱- عکسهای متعددی از چهار حالت نازلها گرفته شد:

۱-۱- نازلهای خارجی نصب نشده (در انبار)

۱-۲- نازلهای داخلی نصب نشده (در انبار)

۱-۳- نازلهای مستهلک خارجی (در کارگاه) با جزئیات نحوه تخریب

۱-۴- نازلهای مستهلک داخلی (در کارگاه) با جزئیات نحوه تخریب

۲- مراجعه به مسئولین نواحی برای سوال از شرایط محیطی (در صورت امکان سنجش دمای نازلها در زمان کار، با Thermometer تشعشعی) و دلایل تخریب و زمان کارکرد خارجیها در مقایسه با داخلیها و اشکالاتی که نازل مستهلک در کار ایجاد می کند (با ذکر مقایسه های ریالی).

۳- آنالیز نمونه داخلی و خارجی جهت اطمینان از مشابهت متریال دو نمونه.

۴- متالوگرافی در هر چهار حالت بند ۱ جهت بررسی ریزساختار نمونه داخلی و خارجی قبل و بعد از کارکرد با یکدیگر.

۵- تحقیق برای مشخص کردن نوع Failure که آیا Erosion , Corrosion یا Creep است.

۶- پس از انجام مراحل ۳، ۴ و ۵ مشخص می شود چه متریالهایی می تواند جایگزین مناسبی برای متریال موجود باشند و کدامیک در صنعت داخل قابل تهیه است و امکان سنجی نصب (میزان Weld Ability) هم چک می گردد.

۷- با توجه به تمام بررسی ها راهکار برای افزایش طول عمر نازلها ارائه خواهد شد.

ج – ارائه نتایج تحقیقات و آزمونهای صورت گرفته :

۱- عکسها نازلهای خارجی و داخلی پیش از کارکرد و پس از آن:

همانطو که در تصاویر مشاهده می شود، با وجود زمان کمتر کارکرد نمونه های داخلی، تخریب آنها گسترده تر و تغییر شکل ظاهری و دفرمه شدن بیشتری نسبت به نمونه خارجی داشته اند. تفاوت دیگری که در قطعه تخریب شده داخلی دیده می شود، سوراخهایی در نزدیکی محل جوشکاری است که به احتمال قوی، ناشی از عدم رعایت دستورالعمل جوشکاری با استفاده از الکترود مناسب جوشکای است.

	
نمونه نازل داخلی نصب نشده	نمونه نازل خارجی نصب نشده

	
نمونه مستهلک نازل داخلی	نمونه مستهلک نازل خارجی

۲- تحقیقات میدانی و استعلام شرایط محیطی از مسوولین نواحی

در مورد نتایج حاصله از پرسش از مسوولین نواحی توضیحات لازم در بند الف گزارش ارائه شده است.

۳- آنالیز نمونه داخلی و خارجی جهت اطمینان از مشابهت متریال دو نمونه

بر روی هر دو نمونه داخلی و خارجی تست PMI توسط دستگاه کوانتومتر پرتابل مدل Spectrotest متعلق به این شرکت انجام گرفت که نتایج حاصله در جدول زیر درج شده است، پرینت دستگاه کوانتومتر نیز در ضمیمه گزارش آمده است:

Comp. / Sample	% Fe	%C	%Si	%Mn	%Cr	%Mo	% Ni	%Al	%Cu	%Nb
Foreign Nozzle	Rest	0.38	0.98	0.43	24.49	0.36	21.53	0.02	0.11	0
Iranian Nozzle	Rest	0.13	0.77	0.22	20.98	0.25	12.32	0.02	0.18	0

مطابق آنالیزهای جدول فوق گرید دو نمونه مطابق جدول زیر می باشد.

Sample	Grade (ACI-US)	Grade (DIN & UNI)	Mat. No.	توضیحات
Foreign Nozzle	HK-40	GX40CrNiSi25-20	1.4848	گرید با توجه به ریختگی بودن تعیین شده است.
Iranian Nozzle	CF-8	GX5CrNi19-10	1.4308	گرید با توجه به ریختگی بودن تعیین شده است

آنالیز دقیق استاندارد دو گرید فوق در جدول زیر بر مبنای استاندارد آلمان آمده است:

Comp. Grade	% Fe	%C	%Si	%Mn	%Cr	%Mo	% Ni	%Cu	% Nb	%Ti
HK-40 ~ 1.4848	Rest	0.30-0.50	1.00-2.50	<2.00	24.0-27.0	<0.50	19.0-22.0	-	-	-
CF-8 ~ 1.4308	Rest	<0.07	<1.50	<1.50	18.0-20.0	-	8.0-11.0	-	-	-

چنانکه مشاهده می شود، متریال نمونه داخلی با نمونه خارجی متفاوت می باشد. متریال نمونه خارجی HK-40 است که تقریبا معادل ریختگی فولاد غیر ریختگی 310S می باشد. فولاد 310S از دسته فولادهای مقاوم به حرارت است. مهمترین تفاوت فولاد HK-40 به لحاظ آنالیز با فولاد 310S، تفاوت در درصد کربن است که افزایش درصد کربن در این آلیاژ باعث افزایش مقاومت به خزش نسبت به گرید غیر ریختگی 310S می شود. متریال CF-8 نیز معادل ریختگی فولاد 304 می باشد که مقاومت به حرارت آن کمتر از فولاد 310S می باشد. آنالیز شیمیایی دقیق گرید های 310S و 304 جهت مقایسه در جدول زیر بر مبنای استاندارد آلمان آمده است:

Comp. Grade	% Fe	%C	%Si	%Mn	%Cr	%Mo	% Ni	%Cu	% Nb	%Ti
310S ~ 1.4845	Rest	<0.10	<1.50	<2.00	24.0-26.0	-	19.0-22.0	-	-	-
304 ~ 1.4301	Rest	<0.07	<1.00	<2.00	17.0-19.50	-	8.0-10.50	-	-	-

علت عدم مقاومت فولاد CF-8 در برابر حرارت نسبت به فولاد HK-40 مقدار بسیار کمتر عنصر نیکل در ترکیب این فولاد نسبت به فولاد HK-40 می باشد.

در مقایسه خواص خزشی فولادهای 304 و 310S، مطابق نمودار شماره ۱ در صفحه ۵ فایل ضمیمه ۲، با وجود اینکه در دماهای زیر ۷۵۰ فولاد 304 مقاومت خزشی بهتری را نسبت به فولاد 310S نشان می دهد اما در دماهای بالاتر از ۷۵۰، به دلیل افت بیش از اندازه مقاومت خزشی، اصولا کاربرد ندارد، اما فولاد 310S در دماهای بالاتر از ۷۵۰ مقاومت خزشی خود را حفظ می کند و این موضوع به دلیل وجود درصد بالاتر عنصر نیکل در آنالیز فولاد 310S و ساختار کاملا آستنیتی غنی از عنصر نیکل می باشد.

از طرفی متریال HK-40 که جنس اصلی نمونه های خارجی است، نسبت به فولاد 310S دارای درصد کربن به مراتب بالاتر (0.3-0.5 در مقایسه با 0.07>) می باشد که خود باعث افزایش مقاومت خزشی این فولاد ریختگی خواهد شد. در واقع کربن با ایجاد کابید کروم، نقش استحکام دهندگی در دمای بالا ایجاد خواهد کرد. به طور خلاصه قوانین زیر را در مورد محتوای کروم، نیکل و کربن در آلیاژهای ریختگی مقاوم به حرارت آهن-نیکل-کروم می توان بیان داشت (فایل ضمیمه ۳):

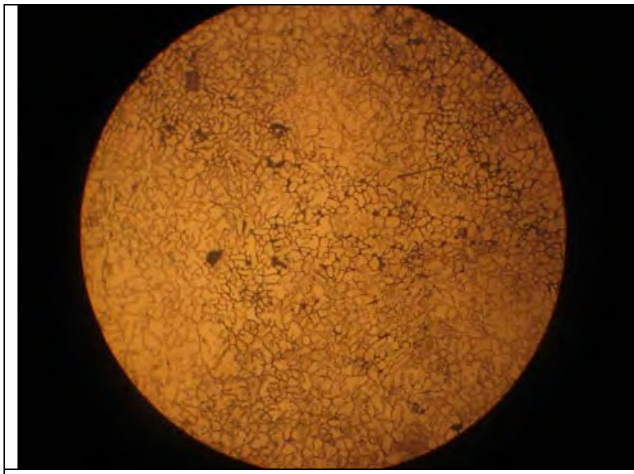
۱- با افزایش درصد نیکل، قابلیت جذب کربن توسط آلیاژ د محیطهای کربوره کننده کاهش می یابد.
۲- با افزایش درصد نیکل، اگرچه استحکام کششی در دمای بالا کاهش می یابد، اما مقاومت به شوکهای حرارتی و خستگی حرارتی افزایش می یابد.
۳- با افزایش درصد کروم، مقاومت به اکسید شدن و خوردگی در محیطهای شیمیایی کاهش می یابد.
۴- با افزایش درصد کربن، استحکام کششی در دمای بالا افزایش می یابد.

۴- متالوگرافی در هر چهار حالت بند ۱ جهت بررسی ریزساختار نمونه داخلی و خارجی پیش و پس از کارکرد با یکدیگر.

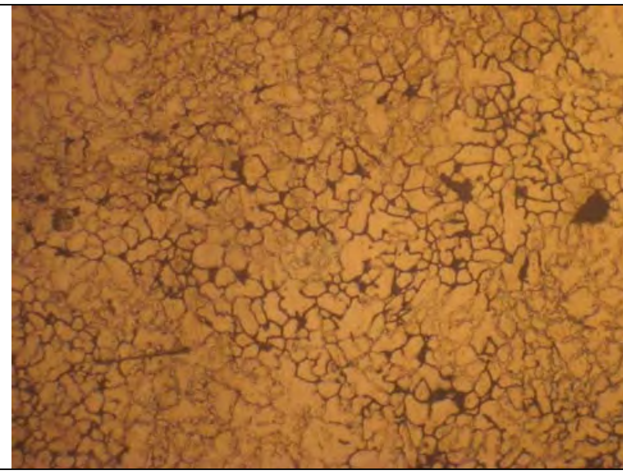
بر روی نمونه های داخلی و خارجی پیش و پس از کارکرد متالوگرافی انجام شد که ریز ساختار تهیه شده و تحلیل آن در زیر ارائه شده است.

۱-۴- نمونه نازل خارجی پیش از کارکرد:

نمونه نازل خارجی پیش از کارکد



1) Etchant Glyceregia 125X

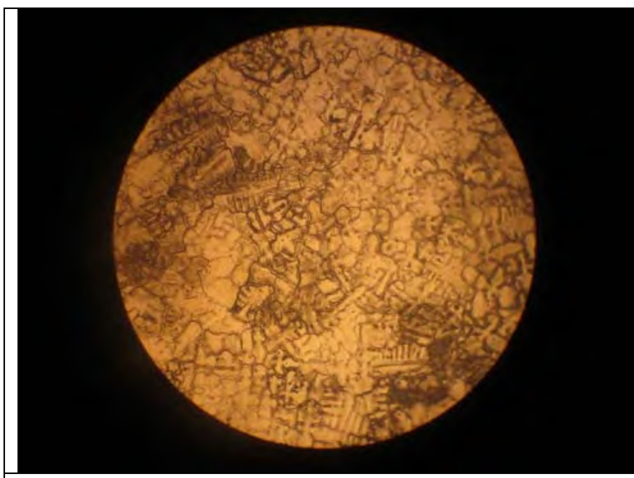


2) Etchant Glyceregia 250X

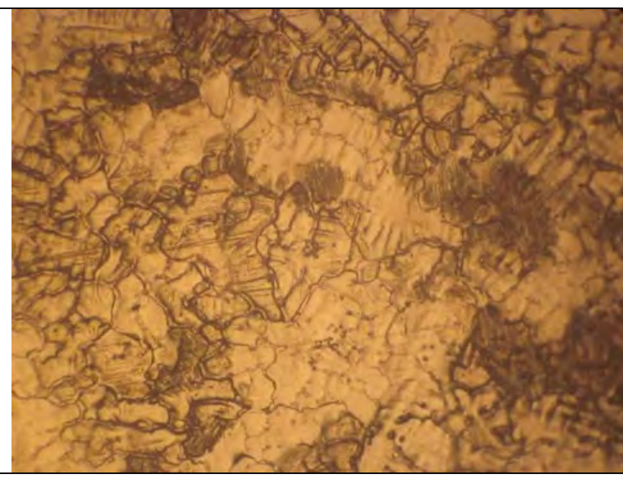
در ساختار فوق دانه های آستنیت مشاهده می شود. به سبب درصد بالای نیکل در آنالیز فاز دلتا فریت که در فولادهای زنگ نزن ریختگی تشکیل می شود، مشاهده نمی شود و ساختار تماما آستنیتی است. در مرز دانه های آستنیت کاربید کروم نیز قابل مشاهده می باشد.

۲-۴- نمونه نازل داخلی پیش از کارکرد:

نمونه نازل داخلی پیش از کارکرد



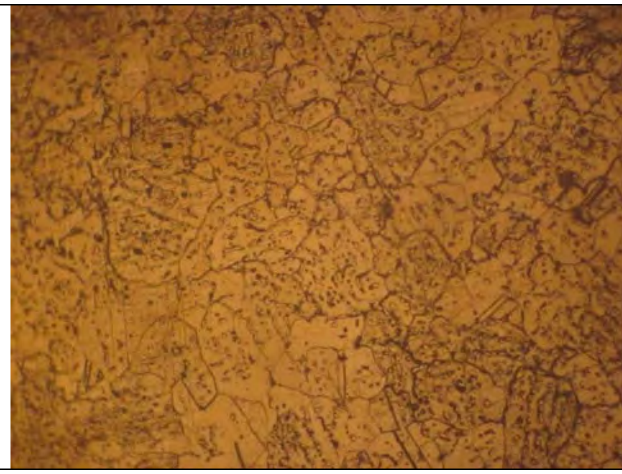
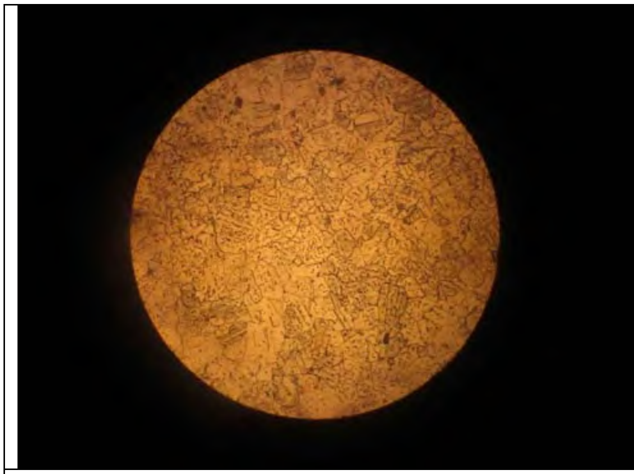
1) Etchant Glyceregia 125X



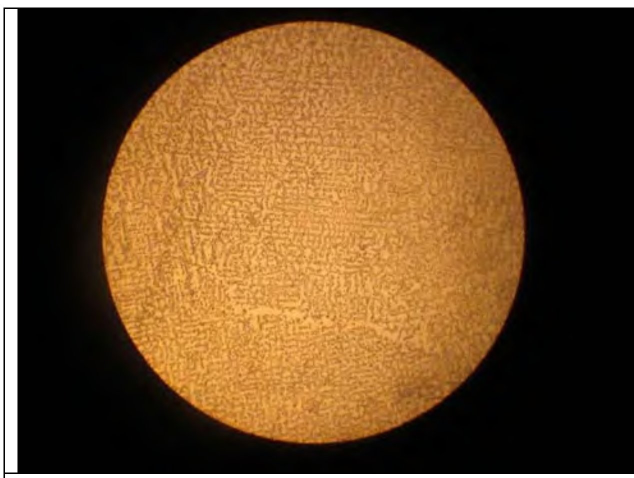
2) Etchant Glyceregia 250X

در ساختار دانه های درشت فاز آستنیت و جزایر دلتا فریت مشاهده می شود. ساختار فوق ساختار نرمال فولادهای زنگ نزن ریختگی است. درصد دلتا فریت در ساختار در حدود ۲۵ می باشد.

۳-۴- نمونه نازل خارجی پس از کارکرد:

<table>
<tr><td rowspan="3">نمونه مستهلک نازل خارجی</td><td></td><td></td></tr>
<tr><td>2) Etchant Glyceregia 250X</td><td>1) Etchant Glyceregia 125X</td></tr>
<tr><td colspan="2">در ساختار فوق دانه های فاز آستنیت، ذرات رسوب کرده کاربید کروم و نیز دوقلویی های آنیلینگ مشاهده می شود. تشکیل دوقلویی های آنیلینگ بر اثر کارکرد نمونه در دمای بالا بوده است.</td></tr>
</table>

۳-۴- نمونه نازل داخلی پس از کارکرد:

<table>
<tr><td rowspan="3">نمونه مستهلک نازل داخلی</td><td></td><td></td></tr>
<tr><td>2) Etchant Glyceregia 250X</td><td>1) Etchant Glyceregia 125X</td></tr>
<tr><td colspan="2">در ساختار جزایر دلتا فریت در زمینه آستنیت مشاهده می شود. ساختار فوق ساختار نرمال فولادهای زنگ نزن ریختگی است. درصد دلتا فریت در ساختار در حدود ۳۵ می باشد.</td></tr>
</table>

د – ارائه راه حل :

پیش از هر چیز آنچه جلب توجه می نماید تفاوت فاحشی است که در آنالیز شیمیایی دو قطعه فابریک و ساخت داخل وجود دارد به طوریکه دو آلیاژ را می توان از دو دسته متفاوت دانست به بیان دیگر جنس قطعه فابریک (HK-40) از دسته فولادهای آستنیتی ریختگی مقاوم به دمای بالا و قطعه ساخت داخل (CF-8) از جنس فولادهای آستنیتی معمولی است که در مورد اولی به دلیل بالا بودن میزان Ni (حدود ۲۱ درصد) ریز ساختار قطعه کاملاً آستنیتی است و این مسئله را با یک آزمون بسیار ساده جذب یا عدم جذب آهنربا می توان اثبات کرد (کاملاً Non Magnet است که نشان دهنده صددرصد آستنیت بودن ساختار است) اما در مورد دوم به دلیل کمتر بودن میزان Ni (حدود ۱۲ درصد) ساختار دارای حدود ۲۵ درصد دلتا فریت است که قطعه را Semi Magnet کرده است. تفاوت فاحش در شکل ساختار نیز در قسمت ج نشان داده شد که در واقع تمامی آزمونهای PMI و متالوگرافی و تست آهنربا یک مطلب را تایید می نمایند. در مورد تاثیر میزان نیکل در مقاومت قطعه در دمای بالا همانطور که پیشتر گفته شد، در واقع تاثیر عمده ای که افزودن نیکل دارد حذف فازهای دلتا فریت می باشد که در دمای بالا مقاومت استحکامی مناسبی ندارند و خزش جنس را تسهیل می کنند و از طرفی افزایش درصد نیکل مقاومت در برابر شوکهای حرارتی و نیز خستگی حرارتی را افزایش خواهد داد. افزایش درصد کربن در آنالیز نیز استحکام تسلیم قطعه در دمای بالا را افزایش خواهد داد، لذا با توجه به پایین بودن درصد نیکل و کربن در نمونه های ساخت داخل که از جنس CF-8 می باشند، احتمال ایجاد خزش (Creep) بسیار زیاد است.

در مورد دو احتمال دیگر تخریب یعنی Corrosion و Erosion با توجه به اظهارات مسئولین سایت که درصد عناصر گازی را ۱۰ درصد CO_2، ۳ درصد O_2 و فاقد CO دانسته اند، می توان نتیجه گرفت که انتظار Corrosion در چنین شعله کنترل شده ای با احتمال زیاد وجود ندارد، همچنین باز هم بنا به اظهار نظر مسئولین که فشار گاز را ۱۶ میلی بار دانسته اند احتمال ایجاد Erosion غیر معمول نیز بسیار پایین است. پس می توان نتیجه گرفت Creep عامل اصلی تخریب بوده است و لازم است جنس ساخت داخل که CF-8 می باشد با جنس فابریک که HK-40 است، جایگزین شود.

در مورد مونتاژ قطعات نازل به بدنه مشعل نیز نکته مهمی که باید رعایت شود، توجه به WPS مناسب با نوع جنس و استفاده از الکترود صحیح است که چنانکه در ضمیمه ۴ دیده می شود، الکترود از جنس ER630 که از دسته فولادهای زنگ نزن رسوب سخت می باشد، مناسب جوشکاری تشخیص داده شده است.

نکته قابل توجه: از آنجا که ریختگری فولادهای آلیاژی مقاوم به حرارت با نیکل بالا در دماهای بالایی انجام می گیرد، آلیاژ سازی این نوع از آلیاژها با تبخیر و سوختن برخی از عناصر همراه است و در نتیجه رسیدن به یک ترکیب ایده آل نیازمند استفاده از تجهیزات و متد مدرن و معتبری است. در همین جا شرکت پارت ریتک آمادگی خود برای انتخاب کارگاههای مناسب برای اجرا و نظارت در حین ساخت با توجه به حساسیت ها و ملاحظات لازم جهت تولید قطعه، همراه با تکرار تمامی تستها از محصولات تولیدی را اعلام می نماید.

TYPES OF STAINLESS STEELS

Stainless Steel is a name given to a group of steel alloys that contain more than 12% Chromium. Chromium has a high affinity for oxygen and forms a stable oxide film on the surface of the stainless steel. This film is called the passive oxide layer and forms instantaneously in ordinary atmospheres. The film is self healing and rebuilds when it has been removed. It is this film that gives Stainless Steel its corrosion resistance.

The large group of stainless steels can be divided into two groups – Austenitic and Ferritic, the Ferritic group being split again into two groups, Martensitic and Ferritic.

AUSTENITIC GRADES

This group of stainless steels contains 17 – 25% Chromium and 8 – 20% Nickel with various additional elements to achieve the desired properties. In the fully annealed condition Austenitic stainless steels exhibit a useful range of mechanical and physical properties. Mechanical properties can be increased with cold working. Welding of this group must be caried out with correct methods but the low Carbon content results in fewer problems than with the Ferritic and Martensitic grades. Normally these stainless steels are non-magnetic but will become slightly magnetic when cold worked. Basic grades of Austenitic stainless steels are listed below.

Description and General Uses

303 Specially developed for machining purposes where production involves extensive machining in automatic screw machines. Sulphur or Selenium is added to give excellent free machining and nonseizing properties. Due to the addition of Sulphur or Selenium the corrosion resistance is lowered to slightly below that of 304. 303 is Non hardenable and not recommended for welding. Non-magnetic when annealed but becomes slightly magnetic when cold worked.

304 The most versatile and widely used stainless steel with the best all round performance. Its Carbon content is lower and its corrosion resistance somewhat higher than 302. It is less susceptible to intergranular corrosion after welding. Non-magnetic but becomes slightly magnetic when cold worked.

304L Type 304L is a very low Carbon stainless steel with general corrosion resistance similar to 304 but with superior resistance to intergranular corrosion following welding or stress relieving. It is recommended for use in parts which are fabricated by welding and which cannot be subsequently annealed. Parts made from this type are generally limited to service at temperatures up to 426ºC. The physical properties and thermal treatments of T304L are similar but not necessarily identical to those of 304. Non-magnetic when annealed but becomes slightly magnetic when cold worked.

310S Type 310S has been developed for high temperature service where high creep strength is required. Its maximum service temperature is approximately1100ºC but it is not recommended for applications of prolonged service as brittleness may occur. Non magnetic when annealed or cold worked.

316 Known as the marine alloy – 316 has a 2-3% addition of Molybdenum which improves the corrosion resistance. 316 has superior corrosion resistance to other Austenitic steels when exposed to many types of chemical corrodents as well as marine atmospheres – 316 also has applications in the chemical, textile and paper industries. It has better strength and creep resistance at high temperatures than 304 and greater work hardening properties. Non-magnetic but becomes slightly magnetic when cold worked.

316L Type 316L is a very low Carbon stainless steel with general corrosion resistance similar to 316 but with superior resistance to intergranular corrosion following welding or stress relieving, It is recommended for use in parts which cannot be subsequently annealed. Parts made from this type are generally limited to service temperatures up to 426ºC. The physical properties and thermal treatments of Type 316L are similar but not necessarily identical to those of 316. Non-magnetic when annealed but becomes slightly magnetic when cold worked.

321 Basically 302 (basic 18/8) stabilised by the addition of Titanium to five times the Carbon content. This prevents intergranular corrosion and offers scale resistance at higher temperatures, up to 850ºC. Corrosion resistance is slightly lower than 304. This grade is not recommended for bright or mirror polishing. Non-magnetic when annealed but becomes slightly magnetic when cold worked.

MARTENSITIC GRADES

This group contains a 12% - 14% Chromium and 0.08% - 2.00% Carbon. The high Carbon content of the martensitic stainless steels allows them to respond well to heat treatment to give various mechanical strengths such as hardness 500004574. However, the Carbon is detrimental when welding and care must be taken. In the heat treated condition, this group of stainless steels show a useful combination of corrosion resistance and mechanical properties that qualify them for a wide range of application.

Description and General Uses

409 Type 409 is a general purpose construction stainless steel. It is primarily intended for automotive exhaust systems, structural and other applications where appearance is secondary to mechanical and corrosion resistance properties.

410 Type 410 is the general purpose corrosion and heat resisting stainless steel. It has good corrosion resistance and can be easily forged and machined. It exhibits good cold working properties. It is the most inexpensive corrosion resistant steel for general purposed, but it not suitable under severe corrosion conditions. 410 is magnetic in all conditions. Frequently used for stainless steel cutlery.

420 Type 420 has a higher Carbon content than 410 to increase hardness to a maximum of approximately 500 Brinell. It has optimum corrosion resisting qualities in the hardened and tempered conditions. Magnetic in all conditions.

431 Type 431 is a Nickel bearing martensitic stainless steel designed for heat treatment to the highest mechanical properties. Its corrosion resistance is superior to that of types 410 and 430. Magnetic in all conditions.

FERRITIC GRADES

This group contains a minimum of 17% Chromium and 0.08 – 2.00% Carbon. The increase in Chromium imparts increased resistance to corrosion at elevated temperature, however the lack of mechanical properties due to the fact that it cannot be heat treated, limits its applications. Like Martensitics they are magnetic and the welding of the group should be carried out with care.

Descriptions and General Uses

430 Type 430 is a corrosion and heat resisting stainless steel with superior corrosion and heat resistance compared with 410. 430 is a non hardenable and possesses only mild cold working properties due to high chromium content. Its weldibility is excellent and it does not require subsequent annealing. Magnetic in all conditions.

DUPLEX / SUPER DUPLEX GRADES

This group of stainless steel has an annealed structure which typically consists of equal parts of austenite and ferrite. These steels have 18 – 29% chromium, 3 – 8% nickel and various other elements, particularly nitrogen and molybdenum. This group of steels has several advantages over austenitic steels. The duplex grades are highly resistant to chloride stress corrosion cracking, they have excellent pitting and crevice corrosion resistance and have about twice the yield strength of the common austenitic grades.,

Description and General Uses

2205 2205 is a duplex stainless steel designed for superior resistance to pitting and crevice corrosion, for resistance to stress corrosion cracking, and for high strength. The steel is well-suited for high chloride environments. Applications include heat exchangers, chemical tankers, chemical reactor vessels, flue gas filters, acetic acid distillation, oil and gas industry equipment.

S32750 S32750 is a Super duplex stainless steel designed for very high resistance to pitting and crevice corrosion, for resistance to stress corrosion cracking, and for very high strength. Applications include oil and gas industries, offshore, petrochemical plants, desalination plants and mechanical and structural components demanding high strength combined with high corrosion resistance

High Temperature Austenitic Stainless Steel

Steel grades

Outokumpu	EN	ASTM
4948	1.4948	304H
4878	1.4878	321H
153 MA™	1.4818	S30415
4833	1.4833	309S
4828	1.4828	
253 MA®	1.4835	S30815
4845	1.4845	310S
4841	1.4841	314
353 MA®	1.4854	S35315

Characteristic properties

- Good resistance to oxidation
- Good resistance to high-temperature corrosion
- Good mechanical strength at elevated temperatures

Applications

Outokumpu Stainless high temperature steels can be and have been used in a number of applications where the temperature exceeds 550°C, e.g. for equipment and components within:

- Iron, steel, and non-ferrous industries
- Engineering industry
- Energy conversion plants
- Cement industry

General characteristics

A common feature of Outokumpu Stainless high temperature steels is that they are designed primarily for use at temperatures exceeding ~550 °C, i.e. in the temperature range where creep strength as a rule is the dimensioning factor and where HT corrosion occurs. Optimising steels for high temperatures has meant that their resistance to aqueous corrosion has been limited. All steels are austenitic, resulting in relatively high creep strength values.

All steels except EN 1.4948 (i.e., all EN 1.48XX) are included in the European Standard EN 10095 "Heat-resisting steels and nickel alloys". EN 1.4948 is included in EN 10028-7 "Flat products made of steels for pressure purposes – Part 7: Stainless steel". All the above steel grades are also included in ASTM A240.

4948 is a creep-resistant variant of 1.4301, with a standardised minimum carbon content for service at temperatures of up to 800°C in dry air.

4878 is a heat-resistant variant of 1.4541, with a slightly higher maximum carbon content. The recommended maximum service temperature for this steel in dry air is also 800°C. There is also a creep-resistant, boron-alloyed, variant of 1.4541, i.e. 1.4941, which is included in EN 10028-7 and in ASTM A240.

153 MA™ is also a variant of 1.4301, with increased contents of silicon and nitrogen, and microalloyed with rare earth metals (REM). This has raised the maximum service temperature (in dry air) to 1000°C.

4833 and **4828** are standardised high-temperature steels for service at temperatures of up to 950-1000°C in dry air. Utilisation in the temperature range 600-900°C can lead to embrittlement of the material. There is also a creep-resistant variant of 4833, EN 1.4950, which is included in EN 10028-7 and in ASTM A240.

253 MA® is a variant of 1.4828 which has an increased nitrogen content and has been microalloyed with rare earth metals (REM). The most suitable temperature range is 850-1100°C, because structural changes when used between 600 and 850°C can lead to reduced impact toughness at room temperature.

4845 is a standardised high-temperature steel for use at temperatures of up to 1100°C in dry air. This steel is also prone to embrittlement after exposure between 600 and 900°C. There is also a creep-resistant variant of 4845, 1.4951, which is included in EN 10028-7 and in ASTM A240.

4841 is a variant of 1.4845 with an increased content of silicon, which has enhanced the steel's resistance to oxidation/corrosion but also made it more susceptible to embrittlement.

353 MA® is an alloy with a significantly higher nickel content than the other steels. Like 153 MA™ and 253 MA® it has increased contents of silicon and nitrogen, and is microalloyed with rare earth metals (REM). The maximum service temperature in air is 1150°C, but after service at temperatures below ~950°C there is a risk for reduced room temperature impact toughness.

Chemical composition

The chemical composition of a specific steel grade may vary slightly between different national (and international) standards. The required standard will be fully met as specified on the order.

Chemical composition Table 1

Outokumpu steel name	International steel No		Typical chemical composition %						National steel designations, superseded by EN			
	EN	ASTM/UNS	C max	N	Cr	Ni	Si	Others	BS	DIN	NF	SS
4948	1.4948	304H	0.05	–	18.1	8.3	–	–	304S51	1.4948	Z6 CN 18-09	2333
4878	1.4878	321H	0.05	–	17.3	9.1	–	Ti	321S51	1.4878	Z6 CNT 18-10	2337
153 MA™	1.4818	S30415	0.05	0.15	18.5	9.5	1.3	Ce	–	1.4891	–	2372
4828	1.4828	–	0.04	–	20	12	2	–	–	1.4828	Z17 CNS 20-12	–
4833	1.4833	309S	0.06	–	22.3	12.6	–	–	309S16	1.4833	Z15 CN 23-13	–
253 MA®	1.4835	S30815	0.09	0.17	21	11	1.6	Ce	–	1.4893	–	2368
4841	1.4841	314	0.07	–	25	20	1.7	–	–	1.4841	Z15 CNS 25-20	–
4845	1.4845	310S	0.05	–	25	20	–	–	310S24	1.4845	Z8 CN 25-20	2361
353 MA®	1.4854	S35315	0.05	0.17	25	35	1.3	Ce	–	–	–	–

Microstructure

For most high-temperature alloys, the composition is optimised with regard to strength and/or resistance to corrosion at elevated temperatures.

Diffusion controlled transformations will occur in the material at sufficiently high operating temperatures. The most common type of reaction is the precipitation of non-desirable phases, which, besides lowering the corrosion resistance by consuming beneficial alloying elements (above all chromium), leads to a reduced toughness/ductility of the material – especially at room temperature.

The precipitates are often intermetallic phases such as sigma, chi, and so-called Laves phases.
In 153 MA, 253 MA, and 353 MA, the formation of sigma phase is counteracted by the relatively high contents of nitrogen in the steels (and carbon in 253 MA). Instead, precipitation of carbides and nitrides can occur in the same temperature range, which can result in an equally low impact toughness at room temperature as for intermetallic-embrittled high temperature alloys. Experience and certain laboratory tests have, however, shown that carbide/nitride embrittled steels have a greater ductility when deformation rates are lower, e.g. in tensile and bending tests.

The best steels with regard to embrittlement are 4878, 4948 and 153 MA.

Characteristic temperatures Table 2

Steel grade	Solidification range, °C	Maximum service temperature in dry air, °C	Hot forming, °C	Solution annealing, °C	Stress relief annealing (min. 0.5 h), °C
4948	1450 - 1385	800	1150 - 850	1050 - 1110	840 - 900
4878	1440 - 1370	800	1150 - 850	1020 - 1120	840 - 900
153 MA™	1450 - 1370	1000	1150 - 900	1020 - 1120	900
4828	1420 - 1350	1000	1150 - 950	1050 - 1150	1010 - 1040
4833	1420 - 1350	1000	1150 - 950	1050 - 1150	1010 - 1040
253 MA®	1430 - 1350	1100	1150 - 900	1020 - 1120	900
4845	1410 - 1340	1100	1150 - 980	1050 - 1150	1040 - 1070
4841	1400 - 1330	1125	1150 - 980	1050 - 1150	1040 - 1070
353 MA®	1410 - 1360	1150	1150 - 980	1100 - 1150	1010 - 1040

Mechanical properties

Whilst Outokumpu Stainless high temperature steels are mainly optimised for oxidation and high temperature corrosion resistance, they also have good mechanical properties, partly due to their austenitic structure and partly due to certain alloying elements.

Design values are usually based on (minimum) proof strength values for constructions used at temperatures up to around 550°C. For higher temperatures, (mean) creep strength values are used.

Mechanical properties at room temperature (minimum values) Table 3

Steel grade	Proof strength $R_{p0.2}$ N/mm²	Proof strength $R_{p1.0}$ N/mm²	Tensile strength R_m N/mm²	Elongation %	Hardness max. HB
4948	210	250	510 - 710	45	-
4878	190	230	500 - 720	40	215
153 MA™	290	330	600 - 800	40	210
4828	230	270	550 - 750	30	223
4833	210	250	500 - 700	35	192
253 MA®	310	350	650 - 850	40	210
4845	210	250	500 - 700	35	192
4841	230	270	550 - 750	35	223
353 MA®	300	340	650 - 850	40	210

Elevated temperature tensile properties

At present, no data is available for 353 MA.

Elevated temperature proof strength, $R_{p0,2}$ N/mm², (minimum values) Table 4a

Steel grade	Temperature, °C											
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948	–	157	142	127	117	108	103	98	93	88	83	78	–
4878	–	162	152	142	137	132	127	123	118	113	108	103	–
153 MA™	245	200	–	165	–	150	–	140	–	130	–	120	110
4828	–	140	128	116	108	100	94	91	86	85	84	82	–
4833	–	140	128	116	108	100	94	91	86	85	84	82	–
253 MA®	280	230	–	185	–	170	–	160	–	150	–	140	130
4845	–	140	128	116	108	100	94	91	86	85	84	82	–

Elevated temperature proof strength, $R_{p1,0}$ N/mm², (minimum values) Table 4b

Steel grade	Temperature, °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948	–	191	172	157	147	137	132	127	122	118	113	108	–
4878	–	201	191	181	176	172	167	162	157	152	147	142	–
153 MA™	280	235	–	195	–	180	–	170	–	160	–	150	135
4828	–	185	167	154	146	139	132	126	123	121	118	114	–
4833	–	185	167	154	146	139	132	126	123	121	118	114	–
253 MA®	315	265	–	215	–	200	–	190	–	180	–	170	155
4845	–	185	167	154	146	139	132	126	123	121	118	114	–

Elevated temperature proof strength, R_m N/mm², (minimum values) Table 4c

Steel grade	Temperature, °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
4948	–	440	410	390	385	375	375	375	370	360	330	300	–
4878	–	410	390	370	360	350	345	340	335	330	320	300	–
153 MA™	570	525	–	485	–	475	–	470	–	435	–	385	300
4828	–	470	450	430	420	410	405	400	385	370	350	320	–
4833	–	470	450	430	420	410	405	400	385	370	350	320	–
253 MA®	630	585	–	545	–	535	–	530	–	495	–	445	360
4845	–	470	450	430	420	410	405	400	385	370	350	320	–

Creep strength

Figure 1 shows the relative creep strength for rupture after 100,000 hours as a function of temperature. Reference steel: 253MA.

It should be noted here that 4948, contrary to the other alloys, is a creep-resistant steel that has been optimised with regard to strength. As an example, it can be mentioned that the creep-resistant variant of 4878, 1.4941, has creep strength values that are 15–20% higher than those for 4948.

For each alloy and temperature, the relative strength has been calculated by dividing the stress value that leads to rupture after 100,000 hours with the corresponding value for 253 MA.

(Diagrams of this type provide a quick and clear presentation of the relative strength of different grades of steel, e.g. 4828, 4833, and 4845 are only half as strong as 253 MA at 800°C, i.e. twice the material thickness is required for "normal" dimensioning.)

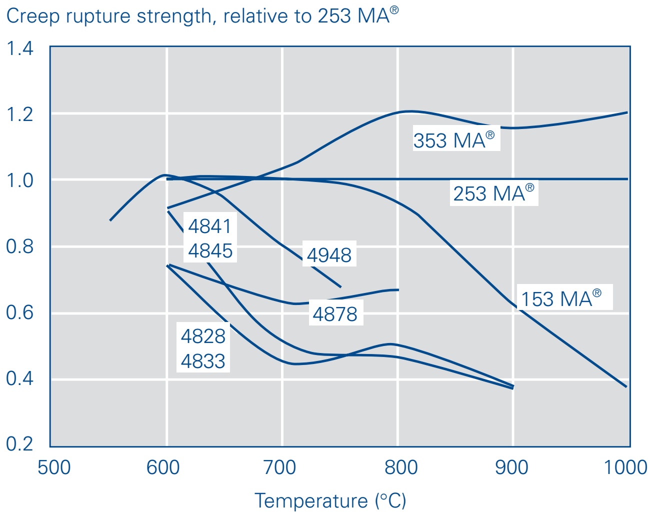


Fig. 1. Relative creep-rupture strength.

Creep rupture strength, $R_{km,10\,000}$ N/mm², (mean values) Table 5a

Steel grade	Temperature, °C 500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948	250	191	132	87	55	34							
4878			142	82	48	27	15						
153 MA™		250	157	98	63	41	25	16	10	6,5	4		
4828			120	70	36	24	18	13	8,5				
4833			120	70	36	24	18	13	8,5				
253 MA®		250	157	98	63	41	27	18	13	9,5	7	5,5	4
4845			130	65	40	26	18	13	8,5				
4841			130	65	40	28	20	14	10				
353 MA®		206	127	82	56	39	28	20	15	11	8	6	4,5

Creep rupture strength, $R_{km,100\,000}$ N/mm², (mean values) Table 5b

Steel grade	Temperature, °C											
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948	192	140	89	52	28	15							
4878			65	36	22	14	10						
153 MA™		160	88	55	35	22	14	8	5	3	1,7		
4828			65	35	16	10	7,5	5	3				
4833			65	35	16	10	7,5	5	3				
253 MA®		160	88	55	35	22	15	11	8	5,5	4	3	2,3
4845			80	33	18	11	7	4,5	3				
4841			80	33	18	11	7	4,5	3				
353 MA®		129	80	52	36	25	18	13	9,2	6,7	4,8	3,5	2,7

Creep deformation strength, $R_{A1,10\,000}$ N/mm², (mean values) Table 5c

Steel grade	Temperature, °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948	147	121	94	61	35	24							
4878			85	50	30	17,5	10						
153 MA™		200	126	74	42	25	15	8,5	5	3	1,7		
4828			80	50	25	15,5	10	6	4				
4833			70	47	25	15,5	10	6,5	5				
253 MA®		230	126	74	45	28	19	14	10	7	5	3,5	2,5
4845			90	52	30	17,5	10	6	4				
4841			95	60	35	20	10	6	4				
353 MA®		149	88	54	34	22	15	10,5	8	6	4,5	3,5	2,7

Creep deformation strength, $R_{A1,100\,000}$ N/mm², (mean values) Table 5d

Steel grade	Temperature, °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
4948	114	96	74	43	22	11							
4878													
153 MA™		135	80	45	26	15	9	5	3	1,8	1		
4828													
4833													
253 MA®		150	80	45	26	16	11	8	6	4,5	3	2	1,2
4845													
4841													
353 MA®		86	52	33	21	14	9,7	6,9	5,1	3,9	3	2,3	1,8

Physical properties

The physical property values given in the European standard EN 10095 (EN 10028-7 for 4948) are inconsistent and poorly documented. The values below have therefore been extracted from STAHL-EISEN-Werkstoffblatt 310 or from own investigations (153 MA, 253 MA, and 353 MA).
If required, values for these properties at other temperatures can be supplied by Outokumpu Stainless, Avesta Research Centre.

Physical properties Table 6

Steel grade	Density (kg/dm³)	Young's Modulus (kN/mm²)			Thermal expansion coefficient (10^{-6}/°C) between 20 °C and			Thermal conductivity (W/m°C)		Heat capacity (J/kg°C)	Electrical resistivity (μΩm)
	20°C	20°C	600°C	1000°C	600°C	800°C	1000°C	20°C	800°C	20°C	20°C
4948	7.93	196	150	120	18.8	19.4	20.0	14.3	26.0	472	0.71
4878	7.92	196	150	–	18.8	19.4	–	13.9	25.8	472	0.74
153 MA™	7.80	200	155	120	18.5	19.0	19.5	15.0	25.5	500	0.84
4828	7.77	196	150	120	18.8	19.4	20.0	12.6	24.7	472	0.87
4833	7.77	196	150	120	18.8	19.4	20.0	12.6	24.7	472	0.87
253 MA®	7.80	200	155	120	18.5	19.0	19.5	15.0	25.5	500	0.84
4845	7.76	196	150	120	18.8	19.4	20.0	11.9	24.3	472	0.96
4841	7.76	196	150	120	18.8	19.4	20.0	11.9	24.8	472	0.96
353 MA®	7.90	190	155	130	16.9	17.5	18.2	11.3	23.0	450	1.00

All these austenitic steels have a greater thermal expansion and a lower thermal conductivity than ferritic stainless steels. This will result in greater thermal stresses when the temperature changes rapidly – thermo-shock – which must be taken into account during design and operation.

Corrosion resistance

Aqueous corrosion

Since most high-temperature materials are optimised with regard to strength and corrosion resistance at elevated temperatures, their resistance to electrochemical low-temperature corrosion may be less satisfactory. Components made of high-temperature material should therefore be designed and operated so that acid condensates are not formed, or at least so that any such condensates are drained away.

As 4878 is a titanium-stabilised grade, it will probably show the best resistance to aqueous corrosion.

High-temperature corrosion

The resistance of a material to high-temperature corrosion is in many cases dependent on its ability to form a protective oxide layer. In a reducing atmosphere, when such a layer cannot be created (or maintained), the corrosion resistance of the material will be determined by the alloy content of the material. Below, a number of high-temperature corrosion types are treated. However, industrial environments often contain a mixture of several aggressive compounds, so the choice of material will, as a rule, have to be a compromise.

Oxidation

When a material is exposed to an oxidising environment at elevated temperatures, a more or less protective oxide layer will be formed on its surface. Even if oxidation is seldom the primary cause of high-temperature corrosion failures, the oxidation behaviour is important, because the properties of the oxide layer will determine the resistance to attack by other aggressive elements in the environment.The oxide growth rate increases regularly with increasing temperature until the rate of oxidation becomes unacceptably high or until the oxide layer begins to crack and spall off, i.e. the scaling temperature is reached.

The scaling temperatures for our steels are not given in Table 2. Instead, a recommended maximum temperature is given for use in dry air, based on laboratory tests and service experience.Table 2 shows that 353 MA and 4841 have the best oxidation resistance, followed closely by 4845 and 253 MA, see also Figure 2.

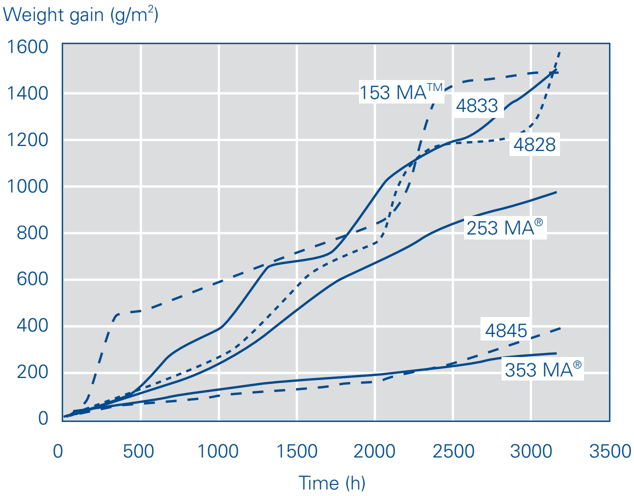


Fig. 2. Long-term oxidation at 1100°C. The specimens were cooled down to room temperature once a week for weighing => 165 h cycles.

The alloying elements that are most beneficial for oxidation resistance are chromium, silicon, and aluminium. A positive effect has also been achieved with small additions of so-called (re)active elements, e.g. yttrium, hafnium, rare earth metals (REM, e.g. Ce and La). These affect the oxide growth so that the formed layer will be thinner, tougher, and more adherent and thus more protective.

Molybdenum has a positive effect on corrosion properties at room temperature and moderately elevated temperatures, but can lead to so-called catastrophic oxidation at temperatures exceeding ~750°C.

The reactive element effect is especially favourable under conditions with varying temperatures, where the differences between the thermal expansion/contraction of the metal and the oxide induce stresses in the boundary layer, thereby increasing the risk of scaling. This explains the relatively high oxidation resistance of the MA alloys.

The existence of water vapour in the atmosphere will reduce the resistance to oxidation and thus the maximum service temperature by up to 100°C. Other, more aggressive components in the environment will lead to even greater reductions of the maximum service temperature.

Sulphur attacks

Various sulphur compounds are often present in flue gases and other process gases. As a rule, they have a very detrimental effect on the useful life of the exposed components.

Sulphides can nucleate and grow due to kinetic effects even under conditions where only oxides would form from a thermodynamic point of view. In existing oxide layers, attacks can occur in pores and cracks. It is therefore essential that the material is able to form a thin, tough, and adherent oxide layer. This requires a high chromium content and preferably also additions of silicon, aluminium, and/or reactive elements.

Under so-called reducing conditions, the oxygen activity of the gas can still be sufficiently high to enable the formation of a protective oxide layer, provided that the chromium content of the material is sufficiently high (>25%). If this is not the case, low-melting-point nickel sulphides can be formed instead. Under such circumstances, a nickel-free (or low nickel) material should be selected.

Carbon and nitrogen pick-up

In small amounts, the pick-up of carbon and/or nitrogen can improve certain properties of a material and is therefore used technically to enhance properties such as surface hardness, resistance to wear, and/or fatigue resistance.

However, excessive pick-up of either element has an adverse effect on the material. In addition to the fact that the carbides/nitrides formed have an embrittling effect, they generally have higher chromium contents than the steel itself. The corresponding chromium depletion in the adjoining metal will reduce the oxidation resistance.

The best protection against this type of corrosion is a dense oxide layer, and consequently strong oxide formers, such as chromium and silicon, are beneficial alloying elements.

Aluminium is favourable with regard to carbon pick-up, but the high nitrogen affinity of aluminium causes a significant reduction in the protective effect of the aluminium oxide under strongly nitriding conditions. In certain applications, however, a high carbon and/or nitrogen activity is combined with a low oxygen content, whereby protective oxide layers cannot be formed. Under such conditions, the bulk composition of the material will determine the pick-up resistance. The most advantageous alloying element in this case is nickel, but silicon also has a positive effect.

In certain applications with high carbon activity, low oxygen activity and moderately high temperatures, a type of catastrophic carburisation, referred to as metal dusting, can occur, manifesting itself as a disintegration of the material into particles of graphite, metal, and oxide.

The risk of carbon pick-up increases when the material is subjected to alternating carburisation and oxidising atmospheres. This can occur in carburising furnaces or heat treatment furnaces if there are oil residues on the material being heat treated, or during decoking in the petrochemical industry. Laboratory tests have shown good results for 353 MA.

The risk of nitrogen pick-up is particularly high in furnaces working at high temperatures with oxygen-free gases, consisting of cracked ammonia or other N_2/H_2-mixtures.

Halogens

Gases containing halogens or hydrogen halides are very aggressive to most metallic materials at higher temperatures.

Aluminium, and in particular nickel, appears to increase the resistance to corrosion in most gases containing halogen. Chromium and molybdenum, on the other hand, can have either a positive or a negative effect depending on the composition of the gas.

Molden salts

In certain industrial processes, molten salts are used "deliberately". These salts easily dissolve existing protective oxide layers and can therefore be very aggressive. However, since the conditions are well known and relatively constant, it is possible to keep the effects of corrosion at an acceptable level by accurate process control and optimum materials selection (a high nickel content is often favourable). However, the detrimental effects of undesirable molten salts can be much worse. The most important example of these effects is caused by deposits on the fireside of various heat transfer surfaces. This type of problem is difficult to reduce or solve by materials selection. Instead, modifications should be made in operational conditions and maintenance procedures.

Erosion

Erosion is a very complex phenomenon, in which not only the properties of the construction material but also those of the eroding particles are significant, e.g. hardness, temperature, velocity and angle of impact.

Generally, an adherent, tough, and ductile oxide layer is required for good erosion resistance. In addition, it should be prone to quick and repeated "spontaneous rehealing". In laboratory tests, 353 MA has shown better results than higher-alloyed material, see Figure 3. The reason for this is probably the improved oxide layer due to the REM additions.

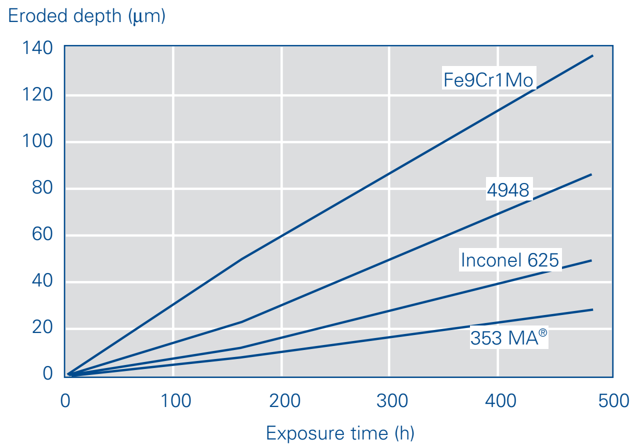


Fig. 3. Results from erosion testing at 550°C.
Source: Rikard Norling, HTC-CTH

Fabrication

Hot and cold forming

Hot working should be carried out within the temperature ranges given in Table 2.

Like other austenitic steels, heat-resistant steels can also be formed in cold condition. However, as a result of their relatively high nitrogen content, the mechanical strength of certain steels is higher and consequently greater deformation forces will be required.

Machining

The relatively high hardness of austenitic steels and their ability to strain harden must be taken into consideration in connection with machining. For more detailed data on machining, please refer to the "Machining guidelines for …" series of brochures, which can be obtained on request. Separate leaflets are available for all of the steels but 4828 and 4833. For these, the guidelines for 4845 are probably the most appropriate.

Welding

The steels have good or very good weldability and can be welded using the following methods:

- Shielded metal arc (SMA) welding with covered electrodes.
- Gas shielded welding, e.g., GTA (TIG), plasma arc and GMA (MIG). Pure argon should be used as the shielding gas.
- Submerged arc (SA) welding.

To ensure weld metal properties (e.g. strength, corrosion resistance) equivalent to those of the parent metal, a filler material with an identical composition should preferably be used. In some cases, however, a differing composition may improve e.g. weldability or structural stability.

Gas shielded welding has resulted in the best creep properties for welds.

More detailed information concerning the procedures for welding these steels can be obtained from Avesta Welding AB. In addition to documents covering welding issues of a general nature, more specialist information is available in the brochures entitled "How to weld 253 MA" and "How to weld 353 MA", which are also available on request from the company.

Heat treatment

Heat treatment after hot or cold forming, or welding will often not be needed, because the material will be exposed to high temperatures during service. However, if that is not sufficient, the best option would be a proper solution annealing, with the second best choice being a stress relief annealing. Suitable temperature ranges for both treatments are given in Table 2.

Components, in which the material has become embrittled during service, will benefit from a "rejuvenating" solution anneal before any maintenance work, e.g. straightening or repair welding, is carried out.

Products

Table 7

Hot rolled plate sheet and strip	Dimensions according to Outokumpu Stainless product program.
Cold rolled sheet and strip	Dimensions according to Outokumpu Stainless product program.
Castings	253 MA® is manufactured under licence by Scana Stavanger AS, Norway, Sarralde SA, Spain, Fondinox SpA, Italy, Highland Foundry Lid, Canada, Tiger Machinery & Engineering Services, the Philippines.
Wire rod and drawn wire (other than welding wire)	253 MA® is supplied under licence by Fagersta Stainless AB, Fagersta.
Welded tubes and pipes	Supplied by Outokumpu Stainless Tubular Products AB
Seamless pipe and narrow strip	253 MA® and 353 MA® are manufactured under licence by AB Sandvik Material Technology, Sandviken.
Welding consumables	Supplied by Avesta Welding AB, Avesta.

Material standards

Table 8

EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10095	Heat resisting steels and nickel alloys
EN 10302	Creep resisting steels and nickel alloys
PrEN 10296-2	Welded steel tubes for mechanical and engineering purposes – Stainless steels
ASTM A167	Stainless and heat-resisting Cr-Ni steel plate/sheet/strip
ASTM A182 / ASME SA-182	Forged or rolled alloy-steel pipe flanges, forged fittings etc for high temperature service
ASTM A213	Seamless ferritic and austenitic alloy-steel boiler, superheater, and heat-exchanger tubes
ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purpose
ASTM A249 / ASME SA-249	Welded austenitic steel boiler, superheater, heat exchanger and condenser tubes
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A312 / ASME SA-312	Seamless and welded austenitic stainless steel pipe
ASTM A358 / ASME SA-358	Electric fusion-welded austenitic Cr-Ni alloy steel pipe for high temperature
ASTM A409 / ASME SA-409	Welded large diameter austenitic pipe for corrosive or high-temperature service
ASTM A473	Stainless steel forgings for general use
ASTM A479 / ASME SA-479	Stainless and heat-resisting steel bars and shapes for use in boilers and other pressure vessels

1011EN-GB:3. Centrum Tryck AB, Avesta, Sweden. Nov 2004.

Outokumpu is a dynamic metals and technology group with a clear target to become the number one in stainless steel. Costumers in a wide range of industries use our metal products, technologies and services worldwide. We are dedicated to helping our costumers gain competitive advantage. We call this promise the Outokumpu factor.

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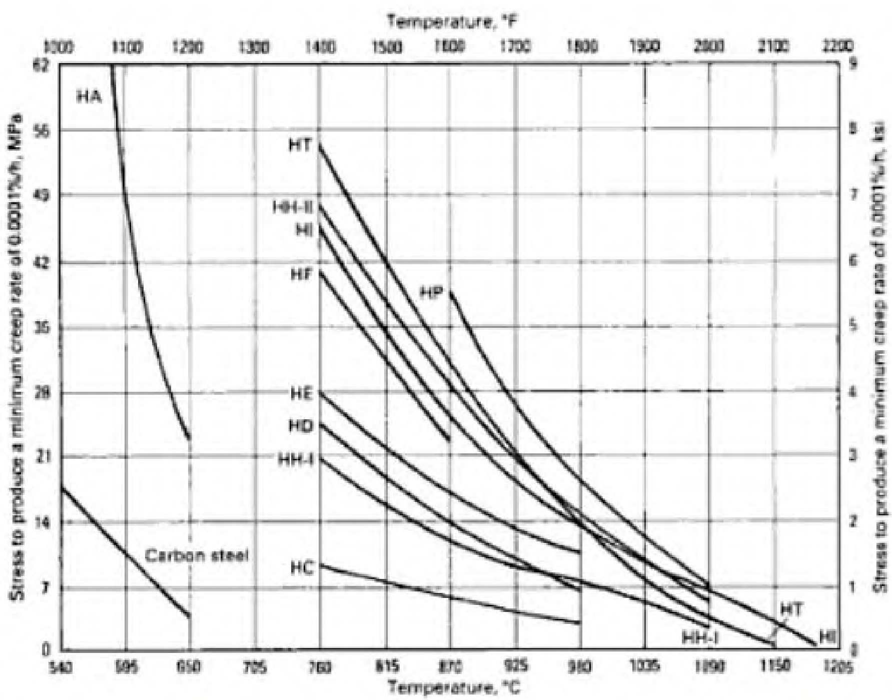

Fig. 12 Creep strength of heat-resistant alloy castings (HT curve is included in both graphs for ease of comparison). Source: Ref 6

subsequent agglomeration. These fine, dispersed carbides contribute to creep strength. A lamellar constituent that resembles pearlite, but that is presumed to be carbide or carbonitride platelets in austenite, is also frequently observed in HK alloy.

Unbalanced compositions are possible within the standard composition range for HK alloy, and hence some ferrite may be present in the austenitic matrix. Ferrite will transform to brittle σ-phase if the alloy is held for more than a short time at about 815 °C (1500 °F), with consequent embrittlement upon cooling to room temperature. Direct transformation of austenite to σ-phase can occur in HK alloy in the range of 760 to 870 °C (1400 to 1600 °F), particularly at lower carbon levels (0.20 to 0.30%). The presence of σ-phase can cause considerable scatter in property values at intermediate temperatures.

tance to corrosion by hot gases, particularly those containing appreciable amounts of sulfur. Because essentially equivalent high-temperature strength can be obtained with either HK or HL, the superior corrosion resistance of HL makes it especially useful for service in which excessive scaling must be avoided. The as-cast and aged microstructures of HL alloy, as well as its physical properties and fabricating characteristics, are similar to those of HK.

Iron-Nickel-Chromium Heat-Resistant Castings

Iron-nickel-chromium alloys generally have more stable structures than iron-base alloys in which chromium is the predominant alloying element. There is no evidence of an embrittling phase change in iron-nickel-chromium alloys that would impair their ability to withstand prolonged service at elevated temperatures. Experimental data indicate that composition limits are not critical; therefore, the production of castings from these alloys does not require the close composition control necessary for making castings from iron-chromium-nickel alloys.

The following general observations should be considered in the selection of iron-nickel-chromium alloys:

- As nickel content is increased, the ability of the alloy to absorb carbon from a carburizing atmosphere decreases.
- As nickel content is increased, tensile strength at elevated temperatures decreases somewhat, but resistance to thermal shock and thermal fatigue increases.
- As chromium content is increased, resistance to oxidation and to corrosion in chemical environments increases.
- As carbon content is increased, tensile strength at elevated temperatures increases.

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Our to produce better steel-based products are the main used in industrial manufacturing various types Heat resistant steel1.4848 plate,1.4848 Round Bar,1.4848 forgings,1.4848 suppliers, 1.4848 Stock,1.4848 sheet, 1.4848 flat bar, 1.4848 pipe,1.4848 tube,1.4848 mould,1.4848 round ingot,1.4848 cold-rolled steel,1.4848 coil,1.4848 strap steel,1.4848 hot-rolled steel,1.4848 medium plate, 1.4848 heavy plate,1.4848 shapped bar,1.4848 hexahedral bar,1.4848,1.4848 slab ingot,1.4848 slab,1.4848 price,1.4848 square bar,1.4848 square steel,1.4848 wire.Extending the industrial all kinds of mechanical industrial parts machining and, at the same time, using fine heat treatment process,tempering,hardening,heating,bright annealing,rotary hearth.chemical composition and Improving mechanical properties of 1.4848.

1.4848

DATA TABLE FOR:PRODUCTS: HEAT RESISTANT STEEL:1.4848

1.4848 properties and heat treatment forged piece, Including **1.4848** application and specifications, We have all specifications, Including **1.4848 steel plate**, **1.4848 sheet**, **1.4848 square steel**, **1.4848 flat bar**,**1.4848 round bar**,**1.4848 forgings**, we can own production and sales.

Introduction to Our Products:

Specialized high quality steel
We have the advantages of equipment, technologies and price
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We can produce the 1.4848 has the following specifications:

Round bar steel: 1mm to 3000mm
Square-shape steel: 1mm to 2000mm
Plate steel:0.1mm to 2500mm
Width: 10mm to 2500mm
Lenth: We can supply any lenth based on the customer's requirement.
Forging: Shafts with flanks/pipes/tubes/slugs/donuts/cubes/other shapes
Tubings: OD: φ6-219 mm, with wall thickness ranging from 1-35 mm.
Finished goods condition: hot forging/hot rolling + annealing/normalizing + tempering/quenching + tempering/any conditions based on the customer's requirement
Surface conditions: scaled (hot working finish)/ground/rough machining/fine machining/based on the customer's requirement
Furnaces for metallurgical processing: electrode arc + LF/VD/VOD/ESR/Vacuum consumable electrode.
Ultrasonic inspection: 100% ultrasonic inspection for any inperfections or based on the customer's requirementExcellent service for all kinds of industries,with advantages of technologies, equipment and price.
We serve you with our honesty, integrity, and professionality.

Chemical composition % of the ladle analysis of grade 1.4848 and Standards

C	Si	Mn	P ≤	S ≤	Cr	Ni	Other
0.30~0.50	1.0~2.5	≤1.5	0.035	0.030	24.0~26.0	19.0~21.0	—

Machining performance

Download 1.4848 the mechanical properties of the report, the report provides detailed performance analysis and application.
Download >>

Principal Design Features

One of the most widely used precipitation hardening grades in the business. While soft and ductile in the solution annealed condition, it is capable of high properties with a single precipitation or aging treatment. Characterized by good corrosion resistance, high harness, toughness and strength.

Machinability

Long, gummy chips characterize this alloys machinability. It can be machined in the annealed condition, however condition H1150M will yield best results. Post machining solution treatment of parts will be required prior to final hardening if machining in this condition.

Heat Treatment

CONDITION A--Soak at 1900 F (1038 C) for 30 minutes and cool below 60 F (16 C) for complete martensite transformation. CONDITION H 950- Treat Condition A material at 900 F(482 C) for 1 hour, air cool.. CONDITION H925, H1025, H1075, H1100, H1150- Soak solution treated material for 4 hours at specified temperature, air cool, CONDITION H1150M- Soak solution treated material at 1400 F (760 C) for 2 hours, air cool, then re-heat to 1150 F (620 C) for 4 hours and air cool.

Welding

Successfully welded by common fusion and resistance methods, this alloy should not be joined by oxyacetylene welding. AWS E/ER630 filler metal is recommended if required.

Forging

Soak for 1 hour at 2150 F (1177 C) prior to forging. Do not work below 1850 F (1010 C). Post-work solution treatment is required prior to final hardening.

Hot tags:***1.4848 steel plate***, ***1.4848 sheet***, **1.4848 square steel**, **1.4848 flat bar**,**1.4848 round bar**,**1.4848 forgings**

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