Metal dusting in the heat treating industry

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Abstract

In recent decades metal dusting has become a costly problem in waste heat recovery systems for various petrochemical processes. There exists a base of experience in the heat treating industry which provides additional information regarding alloy selection for metal dusting environments. Carbon and low alloy steel machine parts are often surface carburised in an atmosphere of N_2, CO, H_2 and CH_4. Metal dusting is a common occurrence in the cooler zones of the furnaces used. The relative performance of materials used for furnace fixturing has been established by experience. Alloy ranking from long term test programmes now in progress correlates well with this experience.

1 Introduction

The atmosphere commonly used for industrial carburising consists of a carrier gas, typically endothermic, with additions of a hydrocarbon gas such as methane. Typical composition (ref. 1) is 39.0% N_2, 19.8% CO, 0.1% CO, 40.4% H_2, 0.2% H_2O, and 0.5% CH_4. The ratio of carrier to hydrocarbon gas ranges from 8:1 to 30:1, dewpoint –4 to –21°C. Failures occur in or near the refractory wall, where temperatures are approximately 600°C, well below furnace operating temperature. Dusting which occurs in 6–12 months is regarded as severe, in contrast to as little as 5 weeks in waste heat boiler service (ref. 2).

2 Experience

In the USA the most common materials used for heat treating furnace components are the wrought grades RA330® (N08330) and alloy 600 (N06600), and the cast alloys HT (J94605), HU (J95405), HK (J94204) and HL (J94614). Used to a lesser degree are the wrought alloys RA333® (N06333) and 601 (N06601), the cast HP (J95705), and NC-11®/22H® (28Cr 48Ni 5W). The cobalt-bearing NC-14®/Supertherm® (25Cr 35Ni 15Co 5W 0.5C) is used for the most severe service. Chemistries are shown in table 1. Rolled Alloys' observations of carburising furnace components have been that N08330 may fail by metal dusting after perhaps 1 to 3 years, but is superior to alloy N06600 in this respect. N06333 is notably better than N08330.
One direct alloy comparison, figure 1,

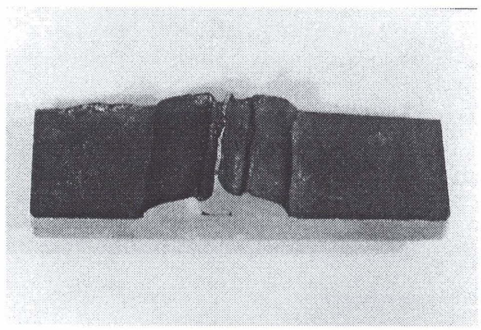

Figure 1. Cross-section of S31008/N06333 flight weldment in rotary carburising retort.

shows two N06333 GMAW beads with only minor surface smoothing while the 4.8mm 310S (S31008) plate between them suffered nearly complete loss of section. This is from a rotary retort used to carburise small parts at an operating temperature of about 950°C. Spiral S31008 flights welded to the inside served to transport work pieces through the retort. As the retort was externally fired, the 7.9mm N06600 shell was above the temperature range for metal dusting. However, at the entry end of the retort the cold-work pieces chilled the S31008 flights to the point that metal dusting was a serious problem.
Metal dusting may occur in radiant furnace tubes in the lower temperature, stagnant zone near where the tube passes through the furnace wall. Figure 2 is the firing end of an N08330 tube used for carburising at 900°C furnace temperature, in an automotive plant, Mid-Western USA. This plant uses both N08330 and cast J94204 radiant

Alloy UNS	W. nr	Nominal chemistry						
		Cr	Ni	Si	Mo	Co	W	Other
N06333	2.4608	25	45	1	3	3	3	18Fe
S30815	1.4893	21	11	1.7	–	–	–	0.17N 0.04Ce 65Fe
S30615	–	18.5	14.5	3.5	–	–	–	1Al 61Fe
S31008	1.4845	25	20	0.5	–	–	–	52Fe
J94605	–	17	35	1.7	–	–	–	44Fe
N08330	–	19	35	1.2	–	–	–	43Fe
NC-14	–	25	35	1.5	–	15	5	13Fe
J95705	1.4857	26	35	1.3	–	–	–	36Fe
N12160	–	28	36	2.8	–	30	–	2Fe
N08120	–	25	37	0.6	–	–	–	0.2N 0.7Nb 35Fe
N06601	2.4851	22.5	61.5	0.2	–	–	–	1.4Al 14Fe
N06006	–	17	66	1.5	–	–	–	13Fe
N06600	2.4816	15.5	76	0.2	–	–	–	8Fe
N07214	–	16	76	–	–	–	–	4.5Al 0.005Y 3.5Fe

Table 1.

tubes for the majority of their work. However, in those furnaces where metal dusting is a significant problem they select tubes of N06333 alloy.
Fan housings in carburising furnaces represent another location susceptible to metal dusting. Figure 3 shows pitting through the 3mm section of an N08330 housing. Furnace operating temperature 927°C, failure location estimated 600–650°C. Normal life is about 1.5 to 2 years, this particular one failed in 6–9 months. The furnace operator had used excess natural gas, thus raising the carbon potential, in an attempt to compensate for furnace leaks. The furnace manufacturer has since switched to 3mm N06333 sheet and a casting of similar composition for new fan housings. See table 1.

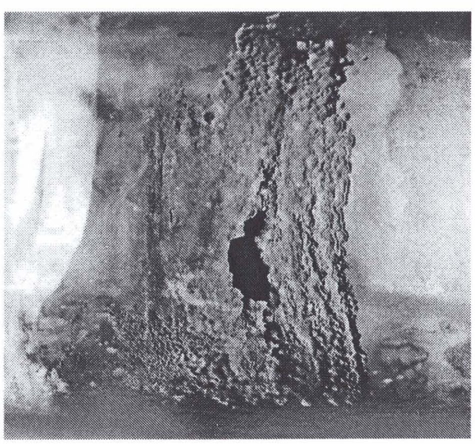

Figure 2. Firing end of 203mm dia. N08330 radiant tube.

3 Testing

The following data are from a continuing test programme using oxygen probes, nominal 33.4mm outside diameter, 3.4mm wall (1" Sch. 40 pipe) of several wrought and cast alloys. The probes are inserted through the roof of a commercial carburising furnace, operating temperature 927°C. Metal dusting occurs where the pipe passes through the refractory, at about 600°C. Furnace atmosphere is endothermic carrier gas enriched with 0.7–0.8 volume %

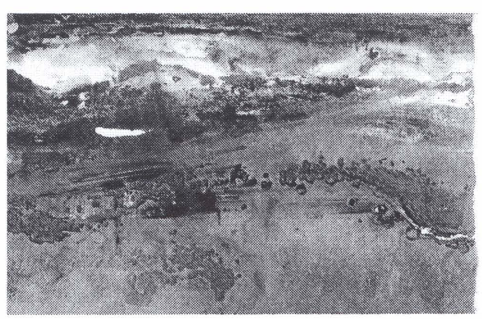

Figure 3. N08330 fan housing.

methane, to a 1.20% carbon potential. Because of the high carbon potential, metal dusting is a serious maintenance problem in this facility. Based on experience they have chosen N06333 for all wrought alloy furnace components and 25Cr 35Ni 15Co 5W 0.5C for castings. The test programme is intended to optimise material selection.

4 Conclusions

Surface finish – a preoxidised surface offers no benefit and may be counterproductive.
Alloy content – aluminium up to 4.5% as an alloy addition is not effective.
High chromium and silicon are beneficial.
Neither high chromium nor high nickel without other alloying additions are sufficient.
Tungsten may be helpful.
Industrial carburising furnace experience has been that dusting problems may be handled by the use of wrought alloy N06333, castings of similar composition or by the cast alloy 25Cr 35Ni 15Co 5W.

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Alloy	Condition	Results
N06333	Machined	Dark, no pits at 27,594 hours
	Preoxidised	Some pits at 16,183 hours
S30615	As received	Black, no pits at 8122 hours
	Preoxidised	Black, no pits at 7549 hours
N08330	As received	Pitted, test stopped at 19,472 hours
N07214	As received	Many pits, test stopped at 19,472 hours
	Preoxidised	Many pits, test stopped at 19,472 hours
N08120	As received	Pitted, removed from test at 11,264 hours
N12160	As received	Pitting started at 24,422 hours
J94605	–	No pits at 8122 hours
J95705	–	No pits at 8122 hours
NC-14	–	No pits at 8122 hours
N06006	–	Pitted, at 8122 hours

Table 3. Times are actual hours in the furnace. Wrought alloys condition 'as -eceived' is annealed and pickled finish. Surface finish of cast alloys not reported.

Some other applications, with life limited by metal dusting					
	Temperature at failure, estimated	Furnace operating temperature	Atmosphere	Component	Life
a	427–760°C	927°C	carburising	19mm dia. anchor bolt N08330	–
b	704°C	900°C	carburising	3mm sheet insulation jacket on fan housing N08330	–
c	427–760°C	954–982°C	N_2 methanol, propane added to 0.95% carbon potential	50×394mm fan shaft, 1750 revolutions per minute, N08330	–
d	677–816°C	816°C max.	carburising	preheat muffle for powdered iron sintering, N08330	9 yr
e	550–650°C	900–950°C	carburising	19mm curtain rod N08330	–
f	927°C	927°C	37% N_2, 37%H_2, 18% CO 5–7% CH_4, , 0.8–1.4% carbon potential	1/2" (12.7mm) Sch. 40 pipe, oxygen probe N08330	1 yr
g	–	954°C	endothermic	1" (25.4mm) Sch. 40 pipe oxygen probe S30815	–

Table 2.

registered trademark of Electroalloys, Division of Abex. 22H® is a registered trademark of Duraloy Technologies, Inc.

References

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2 Michael M. James: 'Unexpected Metal Dusting Failure of Waste Heat Boiler Tubes', conference proceedings Innovative Approaches for Improving Heat Exchanger Reliability, 2–4 November 1998, Houston, Texas, USA, The Materials Technology Institute of the Chemical Process Industries, Inc., p. 3.