Independent Forgings and Alloys Limited

Heat Treatment Plant

No.8 Furnace

Contents Page

Project area:

"To investigate the suitability of ceramics in replacing metallic castings on furnaces"

Background:

Cast components used within forging furnaces are expensive and are very susceptible to heat damage, there is a possibility that new technology within the ceramics industry means that there can be significant cost and operational benefits to using ceramic components on furnaces.

Scope of the project:

Using historical accounting data, the current cost of castings for IFA can be obtained. Liaison with possible manufacturers and determine the cost and expected life of these new available components and materials. Finally sample products can be made and monitored in the production environment.

Introduction to furnace casts

Fig 1: No 8 Furnace (Showing castings)

Figure 1 shows the furnace castings that need to be replaced. The parts that are replaced are:

- 1 off - Arch plate
- 2 off – Jambs
- 2 off – Cill Plate
- 2 off – Doors
- 1 off – Door Plate **(See Appendix for drawings)**

These parts can start from £4,000 and need replacing every two years. (**NB** this is not the only furnace at IFA, there are approximately 12 furnaces in operation with more new ones arriving.)

No. 8 furnace is one of the smallest furnaces therefore the cost of the casts will be different for all furnaces.

The material chosen for the furnaces needs to withstand furnace temperatures in the range of 400˚C to 1250˚C (752˚F to 2282˚F).

Material used for the furnace casts

The material that is currently used for the furnace casts is BS EN 1561 grade 200 (Flake Graphite – Grey cast iron).

Properties: Grey Iron BS EN 1561:1997 (www.thdick.co.uk/grey.htm)

Grade	Minimum Tensile strength N/mm^2	Typical Hardness HB 10/300
200	200	159-194

The strength of the Grey Iron in compression is three to four times the tensile strength because of the planes of weakness created by graphite flakes. The grey iron tends to be brittle compared to steel, but is extremely stiff and deflects little before fracture. Cast iron is strong in compression, but weak in tension.

Grey cast iron also has advantages and disadvantages:

Advantages:

- Have a lubricating effect giving the material advantages in sliding wear applications.
- Better casting characteristics than steel
- Machines more easily and quickly
- Stiff and deflects little before fracture.
- Graphite acts as a chip breaker and a tool lubricant.
- Very high damping capacity.
- Good dry bearing qualities due to graphite.
- After formation of protective scales, it resists corrosion in many common engineering environments

Disadvantages:

- Cannot be readily welded.
- Brittle
- Graphite acts as a void and reduces strength. Maximum recommended design stress is 1/4 of the ultimate tensile strength. Maximum fatigue loading limit is 1/3 of fatigue strength.
- Changes in section size will cause variations in machining characteristics due to variation in microstructure.
- Higher strength grey cast irons are more expensive to produce.

Problems found using this material

BS EN 1561 grade 200 can be the ideal material for furnaces as it can withstand heat up to and above 1300˚C. The material can be brittle therefore the casts in the furnace reacts to the heat, causing the material to expand, which then starts to wear and sometimes fracture.

Replacing this material can be an expensive process costing from £5,000 per furnace (this price includes a pattern that needs to be made for the cast).

Finding an alternative material that is cheap, which lasts longer than two years to produce the cast would be viable for the furnaces at IFA.

Alternative Material

Several alternative materials could be made and used on the casts in the forging furnaces. The types of material to be considered are:

- **Ferrous Material**
  - Cast iron
  - Ductile iron
  - Malleable iron
  - Compact graphite iron
  - Cast steel – Carbon and Low Alloy
- **Non-Ferrous material**
  - Titanium
  - Nickel
- Ceramics

All this material may be acceptable for the forging furnace at IFA but may cost a lot to produce, therefore by comparing the different types of material and also obtaining quotations from respectable companies, a new material for the furnace may be found to replace the grey cast iron.

Properties:

Ferrous

1. **Cast iron** is normally supplied in billet form and is used for producing complex shaped components. Cast iron is strong in compression, but weak in tension.

2. **Malleable Iron** have excellent machining qualities with strength similar to grey irons, but better ductility as a result of closely controlled heat treatment. The type to be consider for the heat

treatment furnace casts is white heart, this is considered as suitable for casting properties.

Type	Grade	Min Tensile Strength	Yield point Strength	Hardness BHN (max)	Elongation %
White Heart BS EN 1562	W22/24	310-340	180-200	248	4
	W24/8	340-370	200-220	248	6

3. **Grey Cast Iron** contains graphite and is used for applications such as machine tool bearing surfaces due to its self-lubricating and vibration damping properties.

4. **Steel** is an alloy of iron with carbon. There are three main types of steels these are Non-Alloy Steel, Alloy Steel and Stainless Steel. Stainless steel contains a minimum of 10.5% of chromium.
   Carbon steels are classified as low, medium and high carbon, low carbon has high ductility and ease of forming; medium carbon retains a good ductility when heat treated and high carbon has great hardness and high strengths.
   Low Alloy Steels generally have less than 1.8% nickel, 6% chromium and less than 0.65% molybdenum. The tensile strength ranges from 450-620 Nmm^{-2} up to 850-1000 Nmm^{-2}

Non- Ferrous

1. **Titanium** is an expensive metal with high strength, low density and a much higher melting point than aluminium. Titanium is important for aerospace and military applications and is being further developed for uses in the off-shore oil industry. Production process is expensive preventing its more general use.

2. **Nickel** is used mainly as an alloying element for stainless and heat-resisting steels. These are used widely in industry and construction. Nickel forms the base metal for a wide range of high temperature alloys (with cobalt) for high temperature applications in turbines and aero engines. It has a relatively low thermal and electrical conductivity, high resistance to corrosion and oxidation, excellent strength and toughness at elevated temperatures.

Ceramics

Ceramics are crystalline, inorganic, non-metals that provide the following generalized material properties, low in density, high moduli, low toughness, and very high melting points, excellent electrical and thermal insulation.

Commonly used ceramics are Alumina, Magnesia, Silica, Silicon Carbide, Silicon Nitride Porcelain, and Zirconia.

Advanced ceramics	
Structural	Wear parts, bio ceramics, cutting tools, and engine components
Coatings	Engine components, cutting tools, and industrial wear parts

Ceramic Manufacturing

The most common forming methods for ceramics include extrusion, slip casting, pressing, tape casting and injection moulding. After the particles are formed, these "green" ceramics undergo a heat-treatment (called firing or sintering) to produce a rigid, finished product.

Structure and Properties

- Metals are ductile and ceramics are brittle.

Most ceramics are:

- Hard,
- Wear-resistant,
- Brittle,
- Refractory,
- Thermal insulators,
- Electrical insulators,
- Non-magnetic,
- Oxidation resistant,
- Prone to thermal shock, and
- Chemically stable.

Current quotations

1. **Quotation from Durham Foundry (Sheffield)**

   Number 8 furnace quotation - £1350.00 per pattern

   £3480.00 for parts

   Total cost for all parts and pattern - £4830.00

Current enquires:

1. **Morgan Advanced Ceramics, Stourport**

   Bewdley Road

   Stourport-on-Severn

   Worcestershire

DY13 8QR

Tel: 01299 827000

Fax: 01299 827872

- Fax sent: 19/08/05
- Responded to enquiry on 22/08/05 with a new contact detail and new department

2. **Fabricast**

Main Street

Hull

HU12 0LF

Tel: 01482 327944

Fax: 01482 216670

- Fax sent: 19/08/05

3. **Morgan Thermal Ceramics UK Ltd.**

Tebay Road

Bromborough

Wirral

CH62 3PH

Tel: 0151 3344030

Fax: 0151 3341684

- Fax sent 25/08/05 to Elaine Gareth
- Fax received back to IFA, IFA to contact Paul Edgell
- Transferred enquiry to another department – still working on a suitable ceramic product for the furnace.

Where to find information:

- AZoM - Metals, Ceramics, Polymers, Composites, An Engineers Resource - http://azom.com/default.asp
- British Standards Online - http://www.bsonline.bsi-global.com/server/index.jsp
- CeramFed British Ceramic Confederation http://business.thisisstaffordshire.co.uk/S/c/e/r/ceramfed/index.html
- CTI Castings Technology International - http://www.castingsdev.com/
- FoundryOnline - http://www.foundryonline.com/
- MatWeb - The Online Materials Information Resource http://www.matls.com/index.asp?ckck=1
- Morgan Advanced Ceramics http://www.morganadvancedceramics.com/materials.htm
- Morgan Thermal Ceramics www.thermalceramics.com

Conclusion and proposal

All research has been successfully completed and material that is not suitable for the furnace cast has been removed from the list.
All drawings for the number 8 furnace have been drawn to scale. These can now be used when sending enquiries to companies about using new material for the furnace.
Several companies have been in contact regarding developing the new furnace casts. So far Morgan Thermal Ceramics are interested in developing and quoting for the new casts but require more information from other departments in their company.
The suitable and cheap product to make the casts for the furnace would be a ceramic/metal composite. This will give the strength of the metal and the resistance of the ceramic, as ceramics are good heat conductor. More research would be required to see about the metal/ceramic composite.

Proposal:

- Keep in touch with Morgan Thermal Ceramics for updates and costing of cast and the type of ceramic to use.
- Contact Casting Technology regarding making a ceramic/metal composite as trials.
- Fabricast can make casts out of ferrous and non-ferrous material, so ask them to quote for a new material cost.

Appendix

- Drawings of Number 8 furnace casts
- Faxes sent
- Research
- Comparison of material

Material	Mixture	Designation USA	Standard	Chemical Composition %									
				Nickel	Chromium	Iron	Silicon	Aluminum	Titanium	Copper	Carbon	Cobalt	Molybdenum
Nicrofer 7520 - alloy 75	Nickel - Chromium - Iron	N06075	BS HR 203	balance	19-21	max 5	0.3-0.7	max 0.3	0.2-0.6	max 0.5	0.08-0.13	0	0
Nicrofer 4626 MoW - alloy 333	Nickel - Chromium - Iron - Molybdenum	N06333	ASTM 718	44-47	24-26	Rest	0	0	0	0	0.03-0.06	2.5-3.5	2.5-3.5
EN-GJL-200 (EN-JL1030)	Grey Cast Iron - Grade 200 (Iron- Carbon)		BS EN 1561:1997				0.75-3.00				2.75-4.00		

Material	Mechanical properties N/mm² (%)	Physical properties							Fabrication Charactersitics		Material description
	Temperature ° C	Tensile Strength N/mm²	Density g/cm³	Specific heat J/kgK	Thermal conductivity W/m K	Electrical resistivity µΩ cm	Thermal expansion 200-300 ° C	Modulus of elasticity KN/mm²	Formability	Weldability	
Nicrofer 7520 - alloy 75	Min 240 , Max 450		8.4	445	12.1	109	13.2	221	good	good	Excellent scaling resistance up to 1100 ° C Gas turbine castings and flame tubes. Components in heat-treatment furnaces
Nicrofer 4626 MoW - alloy 333	Min 180, Max 280		8.2	441	11.1	114	14.7	201	good	good	Nickel - chromium - iron alloy with Molybdenum cobalt, tungsten and silicon additions Excellent high temperature strength above 1000 ° C Components in heat-treatment furnaces
EN-GJL-200 (EN-JL1030)		200-300						88-113			extremely stiff and deflects little before fracture General engineering casts engine cylinder heads, gear boxes and gears