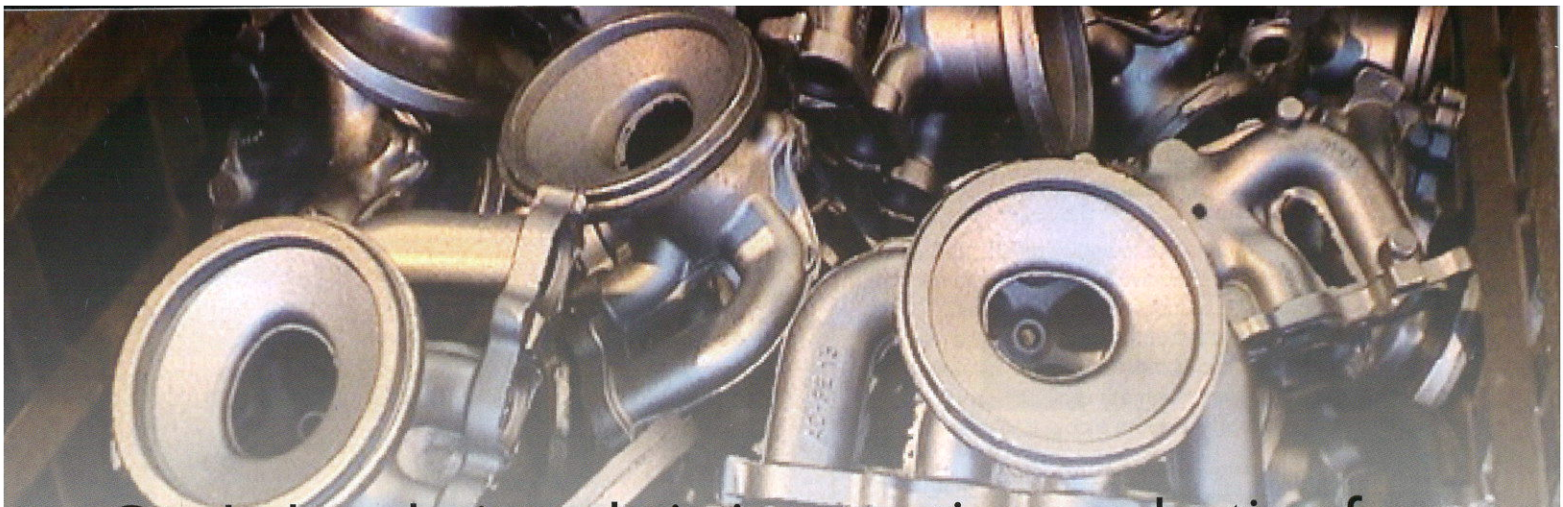


Graded coal - its role in iron casting production from greensand systems

Foundrymen have often regarded coal and carbonaceous additives to greensand systems for the production of iron castings as a 'necessary evil'. Here Alexander Brown of James Durrans & Sons Ltd takes up the story. It is perfectly possible to produce castings with little or no carbonaceous products but experience has shown this is limited to the smaller casting weights and such systems are generally characterised by poorer surface finish and lack of casting definition.

Fundamentally a greensand system is silica sand, bentonite and water. To improve the surface finish, improve casting dimensional stability and to have less sand carryover and cleaner castings at knockout, carbonaceous additives are used to good effect. Surface defects, gas related problems often associated with a poor choice of carbonaceous additive, normally results in reducing or removing this carbon additive as the 'lesser of two evils' and to spend more time at shot blast to clean the castings.

Looking across the foundry industry, coal is still widely used and is the most cost effective carbonaceous additive and even many so called coal substitutes or replacements contain a large percentage of coal. Coal has not only stood the test of time but its set of unique properties actually makes it ideal for iron casting production in greensand systems. It is accepted theory that coal not only provides a lustrous carbon barrier to metal penetration but its ability to produce coke helps create a filler between sand voids, resulting in good surface finish, with excellent knockout conditions.

With the correct choice of coal, the combination of low ash, high volatile and swell index properties coupled with the key element of grading size, ensures castings are produced free from metal penetration and surface related problems.

Coal, like bentonite has two moistures, which need consideration. Surface moisture and chemically combined moisture (inherent), which need to be treated with great respect in storage and processing. This particular property has often given coal a bad press and fires caused by spontaneous combustion have in the past led many foundrymen to seek alternatives.

Horizontal greensand moulding line

By careful selection, safe handling and processing coal continues to offer a good simple cost effective solution. Coal is subject to regulations in storage, processing and transportation and then further subjected to safe handling and use by the foundry. Despite these handicaps, it is still ecomonical to the end user and modern processing and grading methods ensure it is used in the optimum condition.

Safety consideration

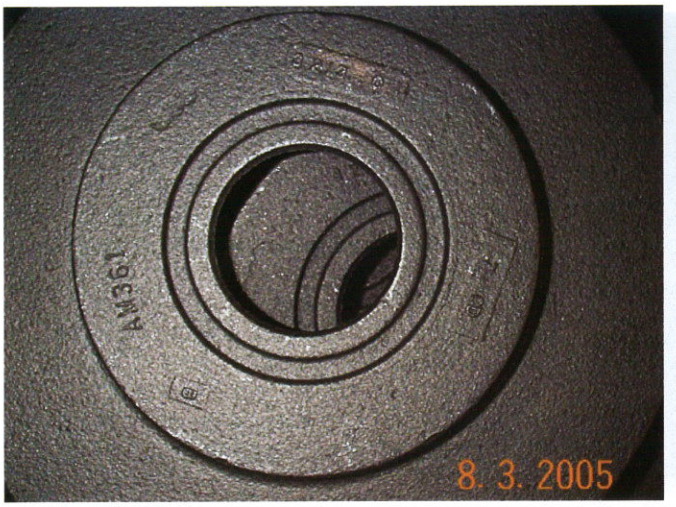
Coal processing plants have to be compliant to the UK directive *DSEAR (Dangerous Substances and Explosive Atmospheres Regulations)* which is in harmonisation with the European *ATEX regulations* and in particular to *zone 21 and 22 for motorised values and controls.* Regular temperature monitoring during processing along with CO measurements ensures safety. Nitrogen purging is an additional safety feature and even after processing, the storage of coal, either in bulk silos or bags, is carefully monitored for temperature before release to the end user.

A further safety consideration is the *ADR regulations ECE/TRANS/140 Volume 1 & 2* (for the safe transportation of dangerous goods) under which coal and blended coal/bentonite/lustrous carbon are classed. Coal and products containing coal are classed as *S2 Organic* (not otherwise specified) *Solid* with a self heating property subject to *UN Number 3088 Class 4.2 regulations.* The *packing groups 2 & 3, bulk loads and bulk polybags* are covered. Currently paper bags, typically 25kg, are not subject to ADR.

As a general rule, tests show that blended coal products *have to contain 50% bentonite* to be out with these ADR regulation rules. Coal and blended products subject to the regulations need to be transported in *dedicated ADR* road transport and bulk bagged products need accredited *UN3088 ADR polybags.* Added to this, the drivers must be specifically trained and licensed and the transport vehicles must display the approved orange placard.

Types of coal

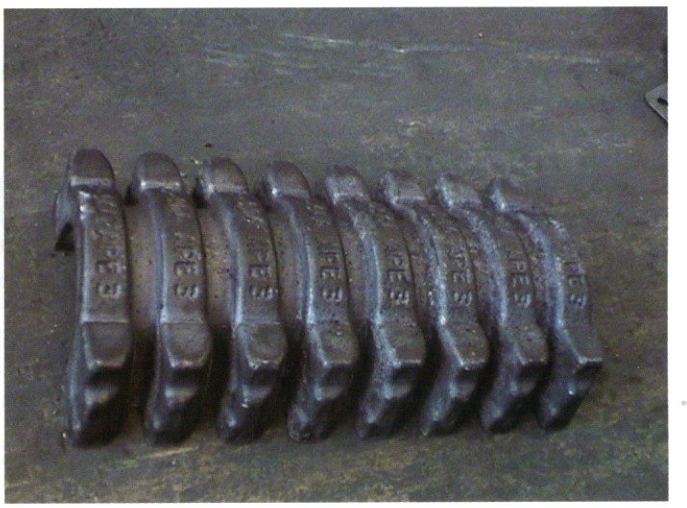
For iron castings in greensand systems, bituminous coals are the logical choice but these vary widely in



Quality surface finish from graded coal

Typical knockout condition using graded coal

Dedicated ADR regulated transport



Classic 'blue' finish from a graded coal greensand system

composition and properties. It is the correct selection of properties that helps produce the ideal carbon additive. Of utmost importance is a low ash content (2 to 3%) coupled with a high volatile (34 to 42%) and a good swell index (2 to 8). These properties can be found in a variety of coking coals. Inherent moisture needs to be considered for safe processing and the production of lustrous carbon is fundamental to good casting atmosphere. Under no circumstances can two or more coals be mixed in processing or final products for safety reasons.

Grading considerations

Graded coal is the term given to ground coals with the fines (particle sizes below 75 microns / 200 #) effectively removed or reduced considerably. If coals are used with over 60% below 75 microns / 200 # they lose some of the activity, simply because the release of volatile is quick and at this very fine particle size they are often removed by extraction systems. A well graded coal is characterised by zero percentage above 1 mm (such particles may cause surface gas blows) and around a maximum of 30% below 75 microns / 200 #. This is only consistently achieved by considerable investment in cyclone type extraction processing allied to screening technology.

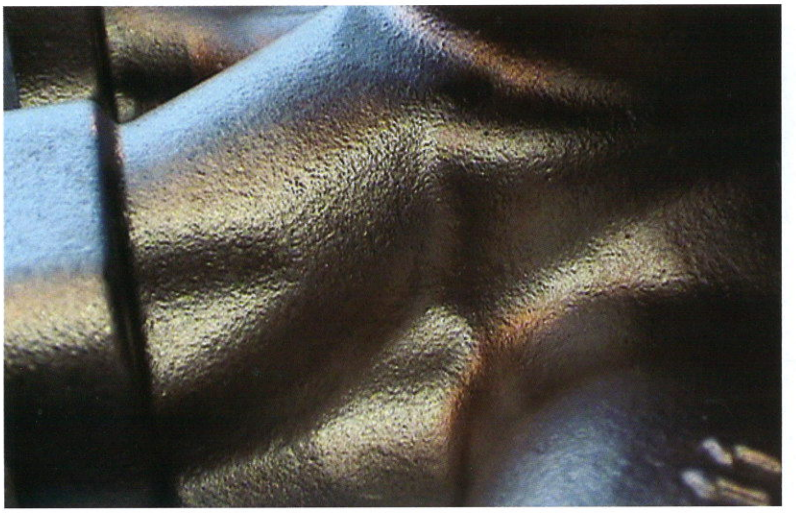
The ideal coal grading is dependent on the casting weight and configuration, coupled with the type of moulding plant and the metal analysis. As a general rule, the finer the detail required the finer the coal grading. High pressure moulding plants, either vertical or horizontal, tend to use the coarser grades as these will aid permeability and the slow release of volatile is a major advantage in these systems. These coarser grades have the ability to re-cycle and therefore have a positive effect, as well as the important coke forming stage which helps increase the total carbon in the system. Total carbon build up is maximised in straight coal systems and is one of the key aspects to a successful operation.

Theory and principles of carbon in greensand systems

Coal is used primarily as a volatile additive coupled with a lustrous carbon formation to ensure metal flows over a deposited carbon layer. This non-wetting barrier to metal penetration is aided by coke formation. At the interface of a moulding sand, coal undergoes a liquid phase expansion which protects against metal penetration. A good foundry coal has minimal direct contribution to moulding properties other than permeability and should be regarded as an essential additive to achieve the desired surface finish and casting dimensional stability.

Other carbon products used in greensand systems tend to be either expensive or have very fast and excessive volatile release and fundamentally they do not have the all round properties of a quality coal. Small amounts can be beneficial when used in conjunction with coal and blended products, including 'one-shot' (combined coal/bentonite/lustrous carbon) but these are normally not as efficient or economical as straight coal/bentonite systems and certainly not as flexible.

Coal in a greensand system is a proven key to improved surface finish, good casting 'peel' at knockout and reduced sand carryover. Coal has a



positive effect on casting dimensions and helps reduce sand related surface defects by producing a reducing atmosphere and with low ash content this helps maintain balanced system moisture.

System sands

System sand is the term given to re-cycling greensand systems. This method was firstly developed as an economical and environmental friendly way to mass produce castings. Sand continually re-cycles, with top ups of bentonite and carbon, and new sand as cores or sand addition, to replace losses to waste or sand carryover at knockout.

It was quickly found that newly prepared facing sands from virgin silica sand simply could not produce good quality castings because they were 'too clean'. These sands lack adequate spent products, coke and other fines that make up the whole picture of a suitable greensand.

System sand moistures are often the key to better control and poor carbon selection is firstly manifested in increased moisture demand. This increased moisture is detrimental to bentonite development and helps create oxidising conditions on casting. This is often characterised by a whitish finish at knockout coupled with poor knockout and excessive sand carryover.

Quality coal, if correctly balanced with bentonite addition will produce reducing conditions and the blue finish often observed in well run systems. Allied to this will be a clean casting strip and minimal sand carryover. These coals with low ash do not put a strain on moisture demand and this allow the bentonite to have ideal conditions for maximum development, resulting in a balanced system with low levels of sand related casting defects.

Basic rules for carbonaceous additions

No two greensand systems are the same and not even two plants in the same foundry as they each have unique properties. Some basic rules apply to all systems and these should form the plan for any control tests and action plans:

- Bentonite: coal by weight averages around 3:1
- Loss on ignition %: volatile % also averages 3:1

Loss of ignition should operate between 4.5% (smaller castings) and 7% (+ 10kg castings) depending on casting size. Systems with less than 4.5% LoI tend to be too clean and lack enough total carbon to be effective in producing good surface finish free of casting defects. Such low systems are prone to produce oxidising conditions instead of the preferred reducing conditions and this is normally evident in the knockout condition with excessive carryover of sand.

Ash in coal should not be above 2.5% otherwise the additional demand for moisture will impact over time on green properties and ultimately on casting performance.

Volatile in coal should be between 30 and 42% and between 1.8 and 2.5% in system sand.

Moisture in coal should always be 1% above the inherent moisture when supplied. System sand moisture will be ideally around 3% and anything above 3.8% should be a major cause for concern.

Grading in coal should match the type of castings and moulding systems and as rule the finer the detail the finer the coal but be aware that finely ground coal (+60% passing 75 microns / 200# with and AFS of 190 +) will be uneconomical and can be extracted out of the system. Modern high pressure moulding lines benefit from coarse (75 grade) to medium (100 grade) grades of coal. These grade numbers refer to AFS numbers.

Total carbon should operate between 3 and 5% again depending on casting size and moulding line but, as a general rule, heavier castings +10kg will operate 4% with +25kg castings around 5%.

Sulphur in coal is typically between 0.7 and 1.3% and in greensand systems sulphur levels will vary between 0.03 and 0.15% depending on bentonite and core sands used in the system. Sulphur in coal is not normally an issue as long as below 1.5%.

Carbonaceous additives other than coal

Many alternatives have been tried and great claims have been laid for complete coal replacements but to date none have successfully replaced coal for the simple reason that coal has many properties that make it ideal for greensand systems. Replacements such as pitch based products are considered dangerous due to health and handling issues and must be used with caution and in very small amounts (<10%). Products such as gilsonite can only be used in small quantities due to fast release of volatile and others such pitch and asphalt based replacements have a string of label warnings that in the long term make them unsuitable. Some replacements are water based slurries of carbon based compounds and again these are much more expensive in the long run and do not give either the surface quality or definition supplied by a good graded coal.

Conclusion

Coal has often been regarded as a problem additive to solve and improve the surface finish of iron castings, but at the same time causes other issues such as increased loss on ignition, total fines and moisture in system sands. With the careful selection of coal, these issues are minimised and the advantages considerably outweigh the problems.

Coal has been undervalued in its use to the foundryman, often regarded as dirty with excessive dust, but in reality coal has been one the keys to quality castings in combination with a quality bentonite. Responsible suppliers will continue to process and transport coal safely and continually search for the ideal coal.

Coal has a massive continuing part to play in the production of quality iron castings and although many alternatives have been tried, there is no real substitute for the all round properties of this wonderful natural resource.

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