Producing Good Quality S.G. Iron Castings in Green Sand

By Dr. P.K Basutkar

List all casting requirements such as material grades, mechanical properties, dimensional, surface finish, heat-treatment (before dispatch from foundry or after machining, e.g. surface hardening, etc.), destructive and non-destructive tests, etc. Determine the process parameters which must be monitored to achieve, meet and verify those requirements.

1. Chemical Composition:

- Select the final casting composition based on the overall casting thickness or on minimum and maximum wall thickness, e.g. CE, C, Si, Mn, S, P, Cu, Ni, Ce, etc.

- For example, ensure that %CE = %C + 1/3 (%Si) < 4.45% to avoid graphite floatation; that %C + 1/7(%Si) > 3.9% to avoid shrinkage; final %Si is ~ 2.45% for nearly all grades of SGI; it should not be too low when carbides may form in thin sections. (%Si must be ≤ 2.0% when low temperature impact properties are required to be met; etc.).

- Remember Mg analyzed by spectrometer is total Mg present in the metal, i.e. Mg present as residual (required for producing nodular graphite, ~ 0.030 to 0.040%); Mg present in Mg-sulfide, Mg present in Mg-oxide, Mg present in Mg-zincate (if galvanized steel scrap is used in melting charge); Mg present in Mg-silicate, etc.

- It is very important to take a proper representative metal sample for Spectro analysis.

2. Raw Materials & Charge Mix:

- Purchase all raw materials, especially those used for metal preparation, to specifications. Back calculate the base metal composition; and, Mg-treatment details and charge-mix required to obtain the final casting composition.

- The ideal charge mix necessary to produce a good metallurgical quality metal consists of 1/3 segregated foundry returns, 1/3 high purity pig iron and 1/3 low-Mn high quality steel scrap either CRCA or deep drawing or extra deep drawing steel scrap. Use low S containing recarburizers. Target base metal carbon ~0.05% higher than required because it is lot easier to dilute the carbon in liquid metal but difficult to raise carbon if it opens lower than target.

3. Melting:

- Determine the charging sequence while preparing base metal in induction furnace. Start with borings, if used in the charge-mix; if not, start with little steel scrap, followed by pig iron and foundry returns.

- Recarburizer should be added when the metal in the furnace is 40 to 70% full.

- If recarburizer is added early or at the start of melting it will form a crown on furnace lining and damage it; if added at the end, it will float on the metal surface and most of it will burn away.

- Fe-Si is best added at the end of melting.

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- For base metal analysis of CE, C and Si rely on CE-meter where a tellurium-coated cup is poured, and the results obtained very quickly.

- CE-meter cannot determine these parameters for Mg-treated metal because it contains very low S. C and Si analyzed by spectrometer are not precise.

- Use Spectro analysis for Mn, S, P, Cr, Cu, Mg, Ce, etc.

- After all the charge is melted, raise furnace metal temperature to ~1420 C. Switch off the power.

- Wait for 2 minutes, de-slag and poor properly taken metal sample into tellurium-coated CE-cup and in Spectro coin sample.

- Keep furnace power off.

- Calculate and weigh corrective additions needed to reach the target base metal composition – %CE, %C, %Si and Mn, Cu, etc.

- Base metal S prior to Mg-treatment should be 0.014 to 0.016% to reduce Mg treatment alloy requirement and to reduce dross in the metal.

- Keep the required pre-conditioner (SiC or pig iron or inoculant grade Fe-Si, etc.) ready along with the corrective additions and wait for metal demand from the molding line.

- When metal demand is received, add the all the corrective additions and pre-conditioner into the furnace and give FULL power to the furnace to reach ~1500 C. When this temperature is reached, switch

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off furnace power, wait 2-minutes for slag to float up to the metal surface, start de-slagging.

- At this time start preparing the treatment ladle by adding the treatment alloy, ~0.2% inoculant, cover steel while packing the additions into the alloy pocket of the treatment ladle.

- Bring the treatment ladle in front of the furnace for tapping and treatment.

- Measure metal temperature, pour a CE-cup, without tellurium coating, for determining the ΔT or recalescence (this is a measure of metallurgical quality of the prepared metal).

- Pour regular CE-cup and Spectro sample and tap the metal for treatment without waiting for the CE-meter and Spectro results because samples are poured to verify that corrections made have met the composition targets. It is presumed that prior studies have been completed in the Foundry to determine and correct ΔT of the base metal and treated and inoculated metal in the Foundry.

- ΔT of the base metal should be ~ 4 to 6C and that of treated and inoculated metal < 3C.

- If treated metal ΔT is between 4 and 7C, it can be corrected to some extent by increased or more effective inoculation.

- If ΔT is more than 7C, metallurgical quality of the treated and inoculated metal is poor.

- This will cause casting problems such as shrinkage, poor nodule count, possible carbide formation, poor machinability, etc.

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4. Pre-Conditioning:

- ∆T of base metal is lowered and brought to 4 to 6C by pre-conditioning. Pre-conditioning is done by using 0.2% SiC (good metallurgical quality SiC or ~5% good shot-blasted pig iron or by adding ~0.3% inoculation grade Fe-Si or Kastwel's Pre KAST to the base metal at ~1450 C).

5. Magnesium Treatment:

- Mg-Treatment and metal handling after treatment: Tap pre-determined weight of the metal (± 5 kg) into the treatment ladle as fast as possible to build up the liquid-metal column over the alloy pocket in the treatment ladle.

- After treatment is over, start the process timer (to ensure that mold pouring is completed within the pre-determined time when Mg- and inoculation-fades have been studied and factored into the process timer setting to ensure that after pouring the last mold of the treatment, the graphite nodularity in castings in >85%, etc).

- After the treatment is over, de-slag, pour a spectro sample for determining the %Mg content of the treated metal (this is required in the initial stages when the Mg-treatment process is being validated).

- It is necessary to determine Mg-loss rate in your Foundry to pre-set the process timer setting during regular production).

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- Similarly, it is important to determine the metal temperature loss, at every stage after Mg-treatment, to ensure that proper precautions are taken to reduce temperature loss during liquid metal processing and handling after treatment to ensure that metal temperature at first mold pouring is ~ 1420 C and it is not below 1375 C at last mold filling.

- This is again a part of validating metal handling and mold pouring practice.

6. Pouring:

- Transfer the treated metal into the pouring ladle while post-inoculating the metal stream.

- Check metal temperature at first and last mold filling.

- After last mold is poured, spectro coin sample, separately cast tensile test bar sample and nodularity test coupon (use of AFS Nodularity test Coupon is strongly recommended) must be poured, using dregs-free, clean metal which is not too cold either.
- Nodularity test coupon is cooled, broken and fractured face quickly polished and checked for graphite nodularity well before the first mold of that treatment reaches the knock-out area (to initiate containment plan should it be necessary).

- In containment procedure, please ensure that at least 2 molds before and 2 molds after the identified bad mold castings are segregated.

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- Pig the left-over metal from the pouring ladle.

- Do not pour fresh metal over the left-over metal heel of the pouring ladle.

- This will cause variation in the silicon content, and dross entrapment in total metal because there will always be slag in the pouring ladle that needs to be removed prior to re-filling of ladle.

- Ensure that charge calculation, charge-mix, charging sequence, metal preparation practices, metal temperatures, de-slagging practice, proper sampling procedure for collecting representative metal samples for CE-cup, spectro analysis, calculation of corrective additions, pre-conditioning, Mg-treatment and inoculation practices are documented and followed strictly for consistent quality of SGI castings produced in all production shifts.

7. Inoculation:

- Recognize that inoculation is a very important part of processing metal for SGI castings.

- Inoculation should be practiced either while tapping the metal from the furnace for Mg-treatment or during Mg-treatment along with treatment alloy (~0.2 to 0.3%), and after Mg-treatment or post treatment as post-inoculation (post-inoculation must raise metal silicon content by at least 0.5% or more), thin walled

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castings need late- or stream-inoculation of 0.010 to 0.15% while mold-filling.

- This silicon increase is to be taken into account when fixing the base metal composition, especially its silicon content.
- Remember that final casting silicon has to be ~2.45% maximum.

8. Knock Out:

- Casting cooling time prior to knock-out: Control casting cooling time in the mold before knock-out. .
- Uncontrolled casting cooling or casting knock-out will cause variation in casting hardness and matrix structure.
- Tensile test sample and poured castings should be removed from their molds at the same time to get representative results of the casting material in the test bar.
- Castings of ferritic grades (400/18, 420/15, 450/12, 500/7) must be knocked-out of the molds below 500 C casting temperature. Casting of pearlitic grades can be knocked out hotter (~ 800C).
- However, this choice is not available on an automated high production molding lines. On such lines the casting final composition must be set and validated based on the available shake-out time of the molding line.

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- In most automated lines this time varies between 40 to 60 minutes after mold pouring. This knock-out practice must be validated while setting up the SGI process.

9. Sand Properties:

- In green sand foundry, it is necessary to control the system and prepared sand properties to ensure consistent production of molds with minimum mold hardness of 85 on the "B" Scale of mold hardness tester. Green sand molds are not rigid molds but for small casting production they are reasonably rigid.

- The following parameters must be controlled and monitored: return sand must be effectively cooled to less than 40 C or say, within about 5 C above ambient temperature in the Foundry shade.

- Prepared sand temperature should preferably be < 40. Prepared sand compactability should be 38 ± 2% at the molding station; water ratio defined as (% moisture/% compactability)* 100) should be 8.5 to 9.0% to restrict free-moisture in the prepared sand.

- Higher free moisture in prepared sand, especially when there is no or improper sand cooling system, increases the 'hot' strength of sand.

- This leads to sand sticking to the casting when castings are knocked out or difficult shake-out.System sand AFS grain fineness number, after clay wash, should be commensurate with the ferro-static head maintained during pouring in the Foundry.

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- This depends on the total mold height and height of the ladle spout above the mold during mold-filling. This system sand AFS number should be ~65 to 70. Remember casting surface finish is decided by this AFS number and NOT by the carbonaceous content of the molding sand.

- Casting finish will be better with higher AFS number and poorer or rougher with lower AFS number. Carbonaceous material in the sand is added to provide a reducing film at the mold-metal interface to prevent oxidation of the molding sand and its sticking to the casting.

- Most casting so-called ‘rough surface’ is metal penetration defect caused by lower AFS number of the system sand of the Foundry.Compactability of the prepared sand at the molding station must be as indicated earlier but that at the sand mixer must be changed and monitored as per ambient conditions or season (higher in summer and lower in rainy season and winter).

- Other prepared sand properties that must be monitored: GCS, permeability (should be as low as possible at ~ 80 to 120); moisture content is adjusted to get the required compactability at the molding station; active clay, total clay and the difference between total and active clay or dead clay (dead clay should be below 4%); loss-on-ignition (LOI) or volatile matter or VM needs to be monitored and controlled.

- Prefer to use coal dust over pitch-type additives during sand preparation. Monitor weight of 50 X 50 mm or 2 X 2” prepared sand sample weight for controlling new sand addition.

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- Total new sand addition is required to be ~2% (including core sand entering the system sand. New sand addition is basically done to ensure that sand levels in the hoppers are maintained and most important the AFS number of fresh new sand added is required to maintain the system sand AFS number around 645 to 70 as mentioned above.

10. Pouring System:

- Pouring system design: Pouring systems must be designed after making the calculations. For green sand SGI castings, PCR or pressure controlled risering system is preferred.

- First the risering system, riser dimensions, riser neck dimensions must be calculated AFTER determining the significant modulus of the casting / casting section where the riser is to be attached.

- Riser dimensions are first determined based on the modulus considerations. Then the riser dimensions are examined for availability of feed-metal and corrected to provide the necessary feed metal. While doing this make sure that the riser diameter is not reduced.

11. Risering:

- Blind risers are preferred for SGI because then the graphitic expansion during solidification is used to partly or wholly compensate for primary liquid shrinkage. This graphite

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expansion is lost to the atmosphere when open risers are used. Use either sand risers or insulating sleeve risers for SGI.

- Exothermic sleeves are not recommended for SGI due to the exothermic sleeve residue entering the system sand at shake-out.

- This exothermic sleeve residue is known to cause a typical ‘fisheye’ defect on the surface of the casting when this residue is seen on the mold surface.

12. **Gating system**:

- The Gating system is calculated and designed after designing the riser system.

- Gating calculations involve determining the choke area, cross-sectional areas of the down sprue, sprue well, runner/s, gates/ mold vents.

- Depending on the number of casting cavities on the pattern and number of ingates used, either a pressurized or a non-pressurized gating system is selected.

- Make sure that the modulus of the ingate is less 20% of the modulus of the casting / casting section where it is attached. This is to ensure that the ingates freeze off and isolate the running system from the casting and its riser system. This also ensures that there is no shrinkage in the ingate.

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- For additional details the reader is advised to refer to the “S.G. Iron Technology Production Practices & Applications” prepared by Kastwel Foundries Dr. P. K. Basutkar, Mr. N. Ramamurthi

For More Information, Please Contact:

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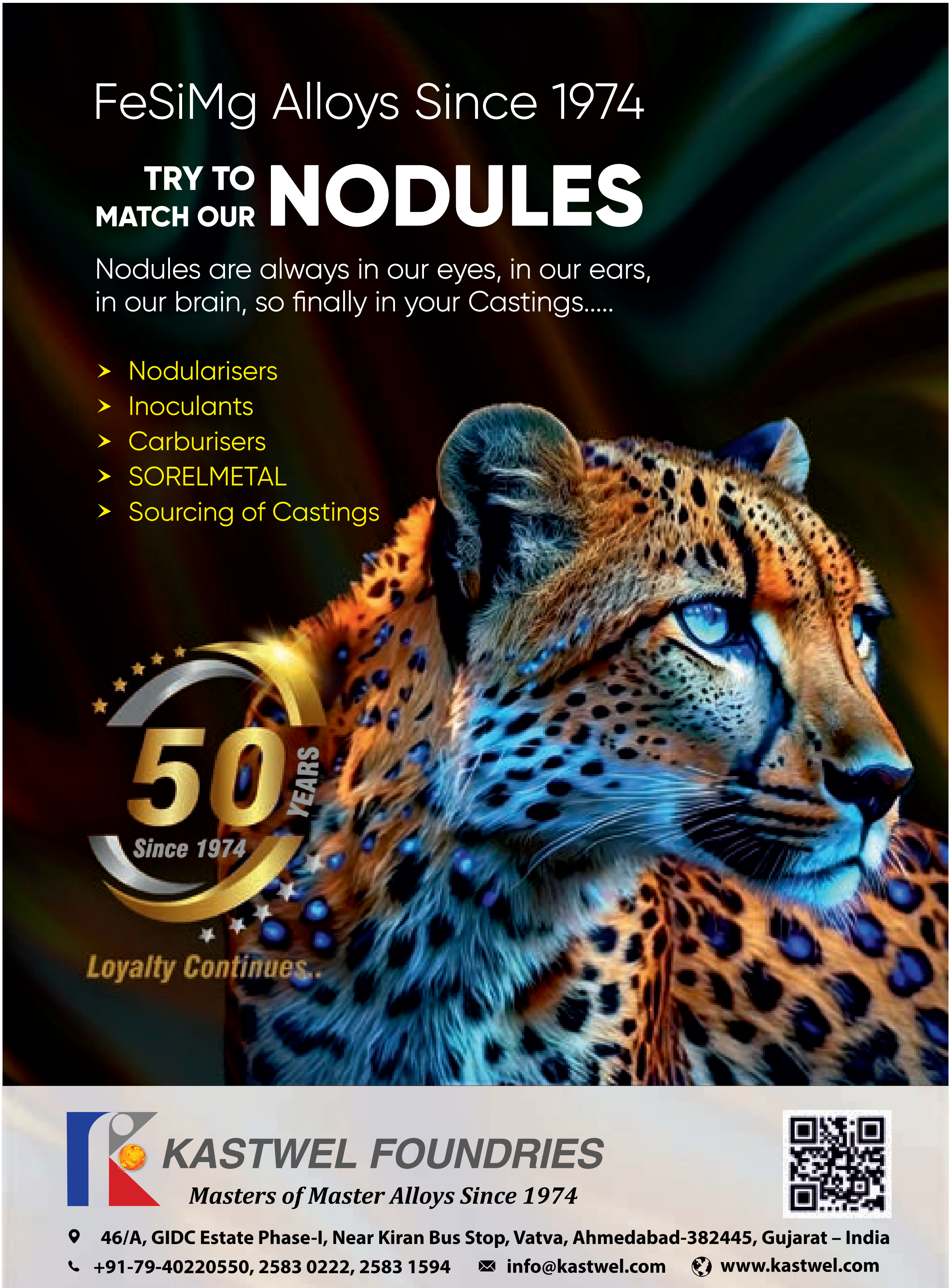
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