THE EFFECTS OF CALCIUM TREATMENT ON THE SIZE AND NUMBER OF INCLUSIONS IN STEEL

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ABSRACT

The size and number of non-metallic inclusions in 3 medium carbon steel melts of 1kg each, treated with 2g, 3g and 5g of calcium were investigated. Samples, measuring 10mm x 20mm were removed from the casts and polished. They were then subjected to optical microscopic examination and the sizes and numbers of inclusions observed were recorded. Results obtained reveal that with increasing calcium addition, the maximum inclusion size decreased from 45 to 30 microns and the number of large inclusions also reduced substantially. In addition, the total number of inclusions decreased from 2,477 in the sample treated with the lowest amount of calcium to 1,917 in the sample with the highest addition of calcium.

SIGNIFICANCE: The presence of inclusions in steel has been and will remain undesirable, because they have morphologies which are detrimental to steel properties. Consequently, a reduction in their size and quantity in steel, which is the aim of this work, is a significant step towards improving steel properties.

KEYWORDS: Inclusions, Morphology, Calcium, Size, Number.

1. INTRODUCTION

Oxygen and Sulphur are regarded as harmful impurities in steel because of the deteriorating effects they have on the properties of steel. Hence, in the early days of commercial steelmaking, their concentrations in steel were usually reduced to the lowest possible levels by using deoxidizing and desulphuring agents such as Silicon, Aluminium and Manganese (Kiessling and Westman, 1970; Grigorian *et al.*, 1983). However, the products of these reactions (oxides and sulphides) can not be completely removed from the steel matrix as some of them are usually formed at the solidifying stage of the steel. Overtime it was discovered that these products of deoxidation and desulphurization reactions – commonly referred to as *primary non-metallic inclusions*, also impair the properties of steel (Kiessling and Westman, 1970; Grigorian *et al.*, 1983). Studies carried out on the effects of inclusions' size and number on the properties of steel reported that the smaller the size of inclusions and the lower their number, the lesser their negative influence on the properties of steel (Kiessling, 1970; Olund *et al.*, 1997; Huet *et al.*, 1997). This is largely due to the fact that steel products with lower amount of inclusions have isotopic mechanical properties. The usual decrease in transverse properties due to inclusions was absent (Knapp and Bolkcom, 1952; Lillieqvist and Mickelson, 1952).

It has also been established that the size as well as the number of the inclusions in a crystallized metal is largely dependent on the concentrations of both oxygen and sulphur in the steel. Consequently, research efforts have been aimed at developing steelmaking techniques that guarantee lower concentrations of these impurities in the steel melt as well as combining the residues into products with geometries for easier removal into slag and morphologies that are more favourable to the properties of steel (Standard E45-97, 2002; Cheng *et al.*, 2003; Karasev and Suito, 1999; Knuppel, 1983).

In this regard, the trend that ultimately captured researchers' attention was the modification of primary inclusions using alkaline and rare earth metals. This is because initial reports on this approach to solving the problem of inclusions in metals in terms of both the size and number were very positive (Simpson *et al.*, 2003). Apart from reducing inclusions' size and number in the steel matrix, there were also reports that the modified inclusions that remain in steel have morphologies that are less harmful to its properties (Simpson et al., 2003; Beskow and Sichen, 2004). One of the rare earth metals that are used for modification is calcium. This element is known to have great affinity for both oxygen and sulphur; hence it is expected that its application to steel will greatly reduce the concentrations of these impurities. This study therefore investigates the effects of calcium addition on the size and number of inclusions in steel.

2. MATERIALS AND METHOD

Three 1kg each of medium carbon steel were remelted in an induction furnace and treated with different quantities of calcium as follows: 2g (melt I), 3g (melt II) and 5g (melt III). After casting, five samples from each of the melts were taken and polished. Samples were then investigated for inclusions' size and number using a computerized optical microscope with a built in-camera at a magnification of 100 to 500. The total area observed for each sample was $200mm^2$. Microphotographs of different parts of the investigated samples were taken.

3. RESULTS AND DISCUSSION

3.1 Results

Microphotographs of some of the polished parts investigated showing non metallic particles at a magnification of 100 are presented in Plate1. Tables 1to 4 show the size distribution of inclusions in the samples investigated. The graphs of the number of inclusions against their size range are shown in Figures 1 to 3. Figure 4 shows the total number of inclusions in the melts.

Plate 1: Microphotographs showing inclusions, x100

Table 1: Size distribution of inclusions in melt I

Sample	Size range, (μm)/Distribution									
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
1	226	147	65	23	10	3	2	1	-	-
2	246	150	74	16	11	2	1	2	1	-
3	253	143	70	21	8	2	3	2	1	-
4	231	123	85	30	15	3	1	1	2	-
5	250	129	75	28	11	4	3	2	1	-
Sub total	1206	692	369	118	55	14	10	8	5	-
Av. inclusions per 200mm^2	241	138	74	24	11	3	2	2	1	-

Table 2: Size distribution of inclusions in melt II

Sample	Size range, (μm)/Distribution									
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
1	341	58	22	10	4	2	1	-	-	-
2	374	39	19	7	2	2	-	-	-	-
3	365	53	22	8	2	-	-	-	-	-
4	294	60	20	6	2	1	1	1	-	-
5	278	46	15	5	3	1	1	-	1	-
Sub total	1652	256	98	36	13	6	3	1	1	-
Av. inclusions per 200mm^2	330	51	20	7	3	1	1	-	-	-

Table 3: Size distribution of inclusions in melt III

Sample	Size range, (μm)/Distribution									
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
1	410	17	8	3	1	-	-	-	-	-
2	400	12	7	4	2	-	-	-	-	-
3	344	15	6	5	2	1	-	-	-	-
4	341	11	6	2	1	-	-	-	-	-
5	298	14	3	3	1	-	-	-	-	-
Sub total	1793	69	30	17	7	1	-	-	-	-
Av. inclusions per 200mm^2	359	14	6	3	1	-	-	-	-	-

Table 4: Total inclusions' distributions in melts I, II & III

Melt №	Size range, (μm)/Distribution										Total
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	
I	1206	692	369	118	55	14	10	8	5	-	2477
II	1652	256	98	36	13	6	3	1	1	-	2066
III	1793	69	30	17	7	1	-	-	-	-	1917

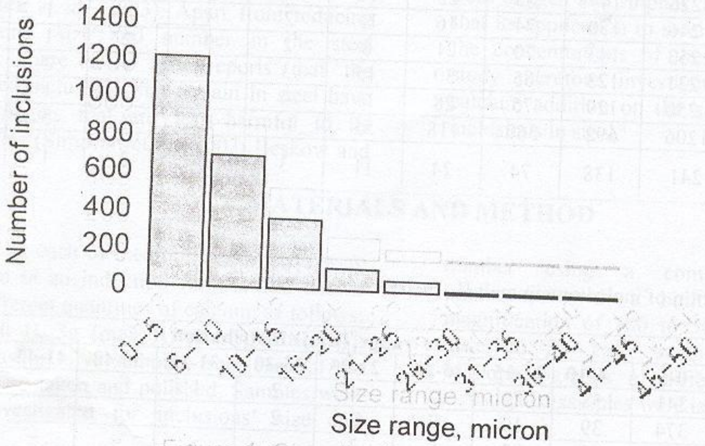

Figure 1: Size distribution of inclusions in melt I

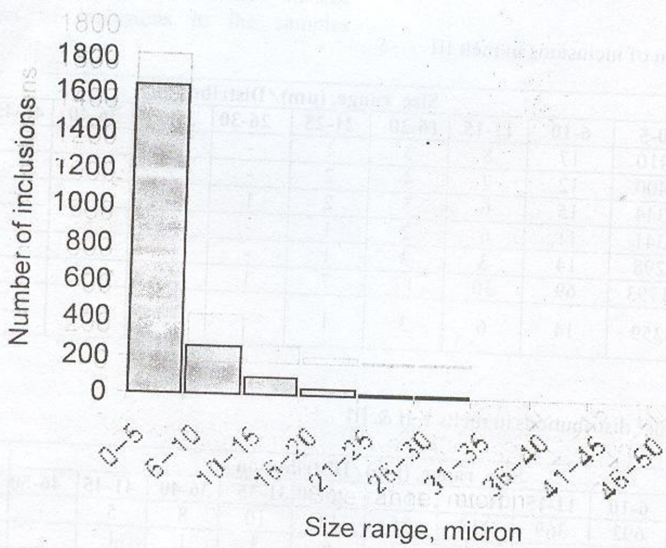

Figure 2: Size distribution of inclusions in melt II

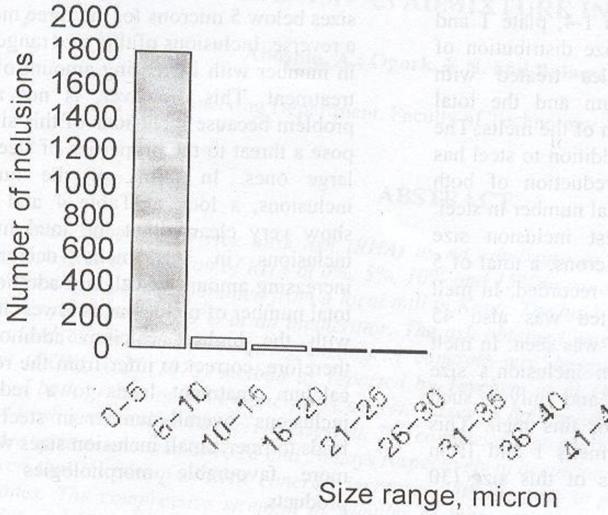

Figure 3: Size distribution of inclusions in melt III

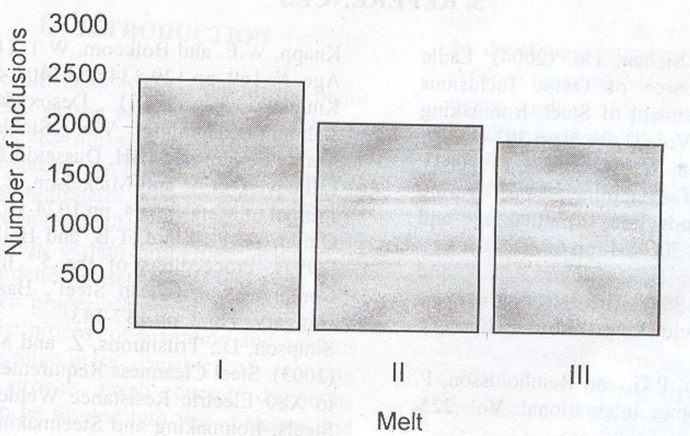

Figure 4: Total number of inclusions in the melts

3.2 Discussion

Results presented in Tables 1-4, plate 1 and Figures 1 to 4 show the size distribution of

Figures 1 to 4 show the size distribution of inclusions in steel samples treated with different amount of calcium and the total number of inclusions in each of the melts. The *results show that calcium addition to steel has* a positive effect in the reduction of both inclusions' size and their total number in steel. *From Table 1, the largest inclusion size* observed in melt I is 45 microns, a total of 5 inclusions of this size were recorded. In melt II, the largest size detected was also 45 *microns but only 1 number was seen. In melt* III however, the maximum inclusion's size observed was 30 microns and only 1 such inclusions was recorded for this melt. This contrast very much with melts I and II in which 14 and 6 inclusions of this size (30 microns) were observed.

But a look at the number of inclusions with sizes below 5 microns for the three melts show a reverse. Inclusions of this size range increase in number with increasing amount of calcium treatment. This, however, is not a serious *problem because inclusions of this size do not pose a threat to the properties of steel like the* large ones. In terms of the number of inclusions, a look at Table 4 and Figure 4 show very clearly that the total number of inclusions in the melts decrease with increasing amount of calcium addition i.e. the total number of inclusions is lowest *in the melt with the highest calcium addition. It* is, therefore, correct to infer from the results that calcium treatment leads to a reduction in inclusions' overall number in steel and also leads to finer, small inclusion sizes which have more favourable morphologies for steel products.

4. CONCLUSION

The results obtained from this study shows that calcium has a positive influence on both the size and the number of inclusions in steel. With increasing calcium addition, the overall number of inclusions dropped from 2477 to 1917, while the inclusion size dropped from a maximum of 45 microns to 30 microns.

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