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Rapid oxide inclusion determination method for steel

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Abstract: In order to inspect the quality of engine valve spring steel, a new algorithm for rapid determination of inclusion characteristics is studied. Principal factor that decides high-grade steel quality depends on size distribution of oxide inclusion or total oxygen in steel. Element composition and size distribution of inclusion can't be determined by the current method of oxide inclusion determination at the same time. A new technology for inclusion determination should be developed since the analyzing time of inclusion in engine valve spring steel takes a long time. In this paper, the determination of alumina inclusion size distribution, inclusion composition, and steel cleanness for the engine valve spring steel are studied by the PDA(pulse discrimination analysis)_OES method. *Copyright © 2008 IFAC*

1. Introduction

Currently rapid determination method for inclusion in steel using the PDA_OES is studied. This method is convenience to analysis inclusion briefly. New method of inclusion determination is developed by our research team using the PDA_OES in 1998 year and the system is upgraded step by step. The information of size distribution and area of inclusion is analyzed by PDA_OES software. Inclusion is determined for several kinds of steel. In the steel making production for spring steel, it is important to reduce alumina inclusion in steel. An alumina inclusion in steel making process is well generated. But total quantity of inclusion is being reduced and cleanness of steel is being improved by our effort. Engine valve spring steel is high strength steel and is sensitive to inclusion in steel. The valve spring on the engine have to guarantee running distance 100,000km. Accumulated fatigue in the spring break to damage from inclusion. Therefore size and a number of inclusions in spring steel have to reduce from steel making process. The class of a steel product in the steel making process is changed from the general steel to the high-grade steel slowly. The need of on-line control for the production of clean steel has driven the development of this method for rapid determination of micro-inclusion characteristics. The standard samples of the inclusion were fabricated by steel making process and were analyzed these samples. And the possibility for the determination of inclusion characteristics is confirmed by this technology. A new algorithm for rapid determination of the inclusion characteristics was developed.

2. Experimental Work

The Optical Emission Spectrometer consists of four units: high voltage generation unit, electric spark generation unit, optical spectrum measurement unit, and signal processing unit as shown in Fig.1. The system was coupled with pulse discriminator equipment. The function of pulse discriminator can display the optical signal intensity in time scale. The spectrometer was operated at a spark frequency of 300 Hz using sample stand with a high voltage source. This system has 16 or 32 element channels for element analysis. The important elements are Al, Si, Mn, S, P, C, Ti, Mg, Ca, Ni, and etc. The intensities of the each element channel in the time-axis are displayed on the monitor of signal-processor simultaneously.

3. Results

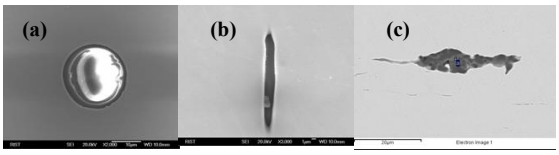


Fig.1 : (a) inclusion shape in bloom using SEM
(b) inclusion shape in billet using SEM
(c) inclusion shape in 8mm wire rod using SEM

Fig.1-(a) shows the inclusion shape in bloom and Fig.1-(b) shows the inclusion shape in billet and Fig.1-(c) shows the inclusion shape in wire rod. These shapes are typical inclusion shape of engine valve spring steel. Fig.1-(a) shows a typical inclusion shape that has melting point of low temperature and an inclusion status before rolling process. So, inclusion shape in bloom is spherical type. Fig.1-(b) shows a hot rolled inclusion that has thin and long shape in the billet. Fig.1-(c) shows a crushed inclusion that consists of soft type like paste in the 8mm wire rod. Most of inclusion in wire rod is crushed by hot rolling process and the size of inclusion is sub micron. Over 10 μm thickness size of inclusion in wire rod have trouble to a factor of fatigue destruction in engine valve spring. The length of inclusion is independent of the fatigue destruction in spring. But a too much lengthened inclusion is harm to spring fatigue and it is a proof of existence of a big size inclusion in the steel. In general, the Al_2O_3 type inclusion is crushed and the SiO_2 type inclusion is lengthened during the hot rolling process.

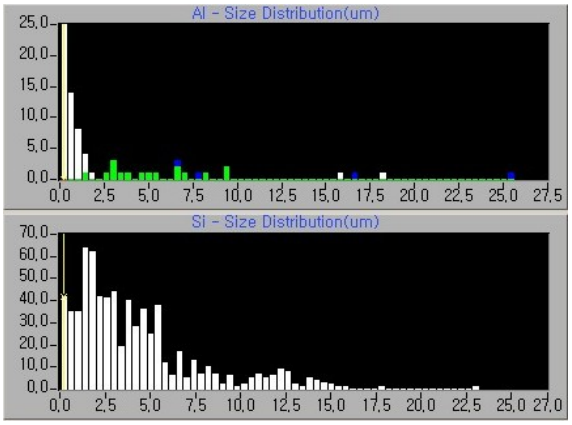


Fig.2 Size distribution of inclusions in bloom using PDA_OES

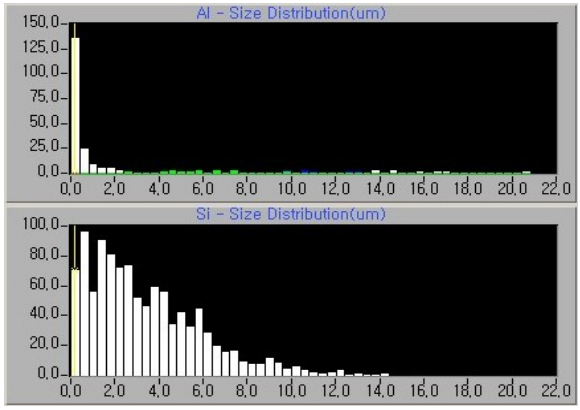


Fig.3 Size distribution of inclusions in billet using PDA_OES

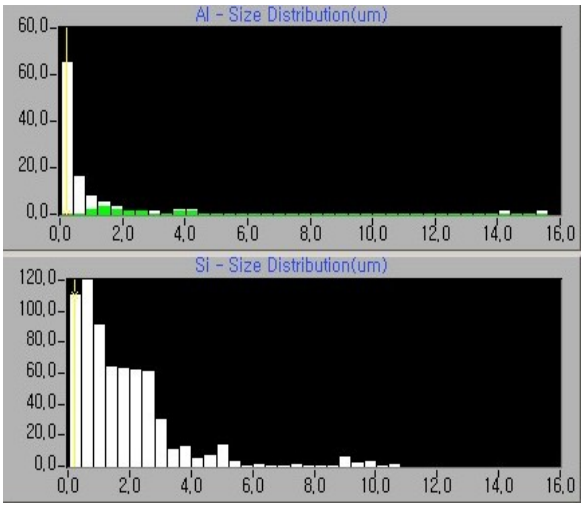
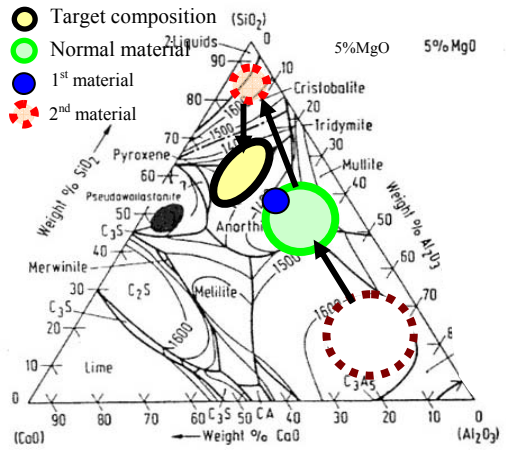


Fig.4 Size distribution of inclusions in wire rod using PDA_OES

Fig.2 shows the size distribution of inclusions in bloom using PDA_OES and Fig.3 shows the size distribution of inclusions in billet and Fig.4 shows the size distribution of inclusions in wire rod with diameter 8mm. These figures are one to one corresponded with inclusions of Fig.1 (a), (b), and (c). Fig.4 shows the crushed inclusions by hot rolled process. It all or just goes to show you that the performance of our developed inclusion measurement system is more excellent than other a pre-existing measurement system. Fig.5 shows the



Inclusion effect for fatigue characteristic
: Al_2O_3trend inclusion (100%), (very harmness)
High melting point Anorthite (50%),
Low melting point Anorthite (harmlessness)

Fig.5 state diagram of composition control for major inclusion

state of major inclusion for a several material and Al_2O_3 rich inclusion has hard characteristics type. Fig.5 shows state diagram of 3 element compositions of inclusion in steel. The dot line circle in Fig.5 shows inclusion composition in commercial valve spring steel. Next circle is inclusion composition in normal material of valve spring steel and next solid circle is inclusion in 1st developed material steel. The next dot circle is inclusion composition in 2nd developed material steel. The normal material steel contains 30~40% Al_2O_3 inclusion in total inclusion and 1st developed material steel contains 20~30% Al_2O_3 inclusion in total inclusion, and 2nd developed material steel contains sub 10% Al_2O_3 inclusion in total inclusion. Inclusion composition is controlled like Fig.5 by our coworker. The more contents of aluminum composition of inclusion, the more hard inclusion are formed. The 1st developed material steel and the 2nd developed material steel have soft inclusion type and the inclusions are lengthened like thin and long type when billets are rolled in temperature condition 1000℃. The phenomenon of the lengthened inclusion causes of soft characteristics of inclusion.

4. Conclusion

Using the PDA_OES system, we certify possibility to detect the micro-inclusion in the engine valve spring steel in a short time. We developed a new algorithm for rapid determination of micro inclusion characteristics (complex inclusion size distribution, inclusion composition ratio etc) in steel. It is important that the composition ratio of alumina in inclusion is controlled in below 20% and the most inclusions are lengthened during the hot rolling process. The thickness size of inclusions is controlled below 10 ㎛ and these inclusions are independent of fatigue in the rotary banding test.