

Assessment of Cleanliness in Interstitial Free Steel

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Tata Steel

Typical composition of IF steel

C (ppm)	Mn	S	P	Si	Al	N (ppm)	Ti
20	0.06	0.008	0.011	0.005	0.035	23	0.06

All are in wt%, unless mentioned otherwise

Two important requirements of IF and LC Al-Killed Steels:

- Stringent Surface Quality
- Excellent formability

Non-metallic inclusions impair both surface quality and formability

Steel cleanliness requirement for IF steel

Steel product	Max impurity fraction, ppm	Max inclusion size
IF Steel (automotive & deep-drawing sheet)	C ≤ 30 N ≤ 40 T.O ≤ 40	100 Micron

Ref: Zhang et.al, 85 Steelmak Conf, 2002, p.431-52

Steel Product Requirements – Japanese Plant:

T.O <30 ppm – direct shipment, no special inspection

T.O - 30 – 55 ppm – critical inspection

T.O > 55 ppm – downgraded

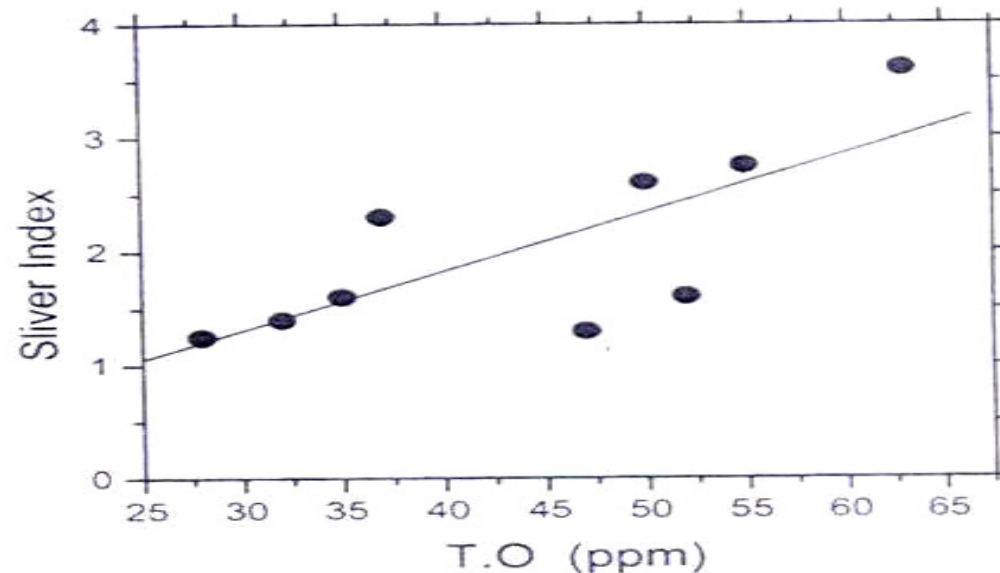
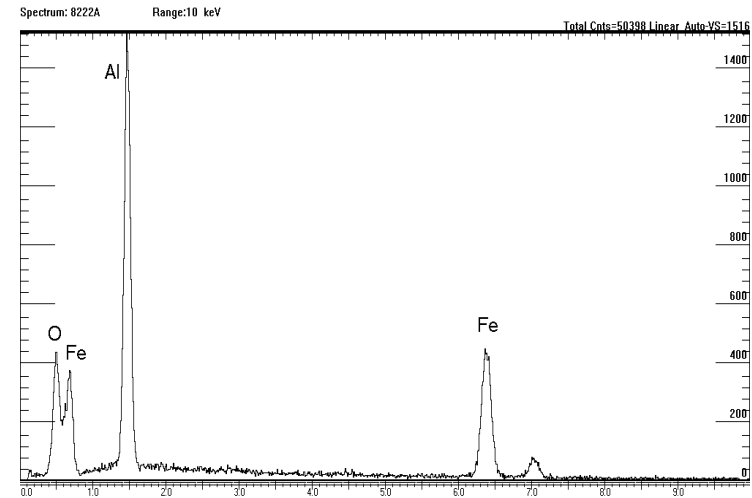


Fig.4 Relationship between T.O in tundish and sliver defect index for product

Ref: Zhang et.al, 85 Steelmak Conf, 2002, p.431-52

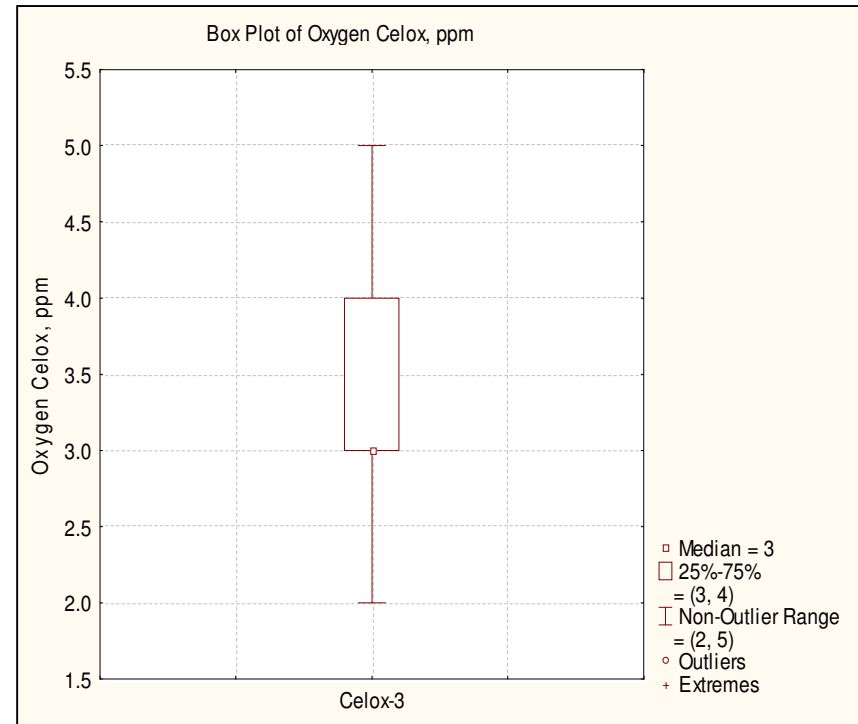
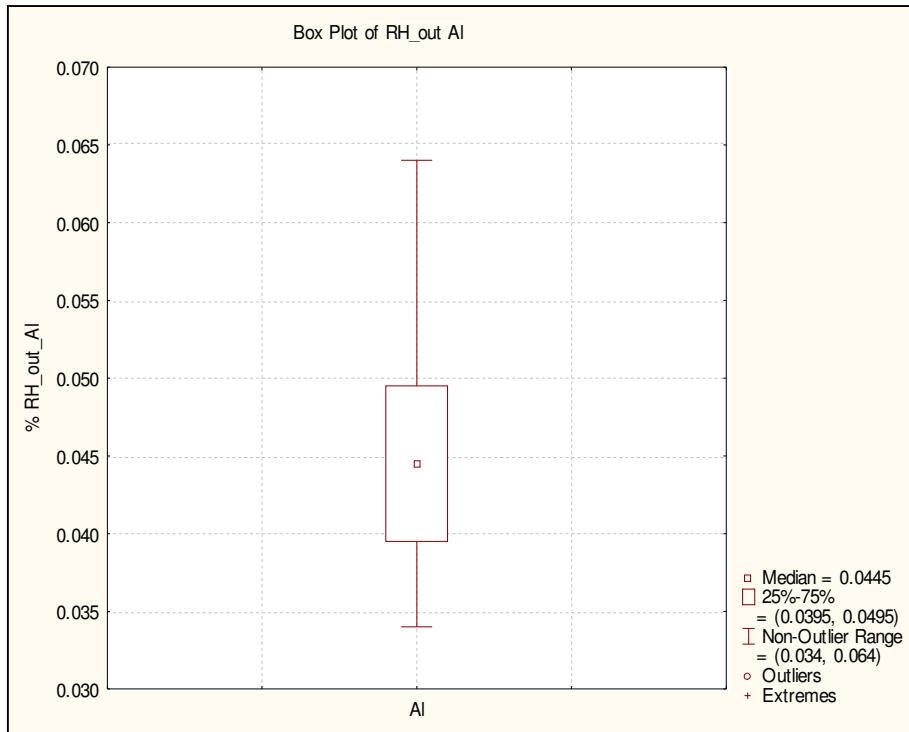
Sliver in IF coil originated from non-metallic inclusions



Clean Steel \longrightarrow Low Inclusions

How to measure ??

Several Direct and Indirect Methods for Steel Cleanliness Measurement



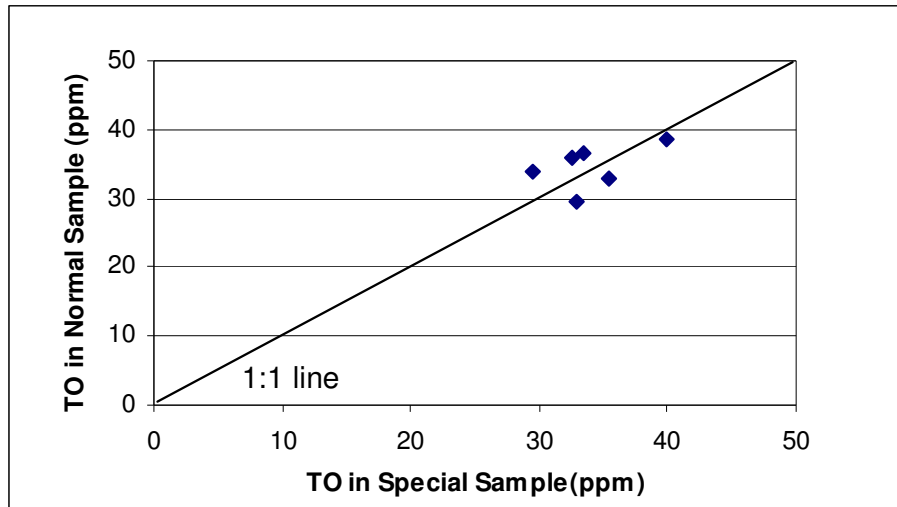
Total Oxygen is generally accepted as a measure for steel cleanliness

Steel cleanliness can also be assessed using ultrasonic C scan image analysis technique

Steel Cleanliness – TO Approach

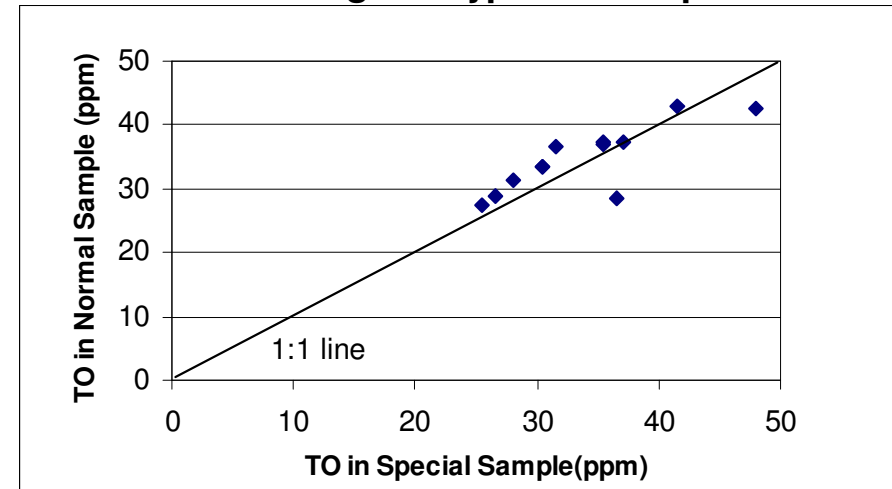
Two types of samplers used:

1. Special Cylindrical Sampler designed by NSC, Japan
2. Normal Dual Thickness Lolly-pop Sampler



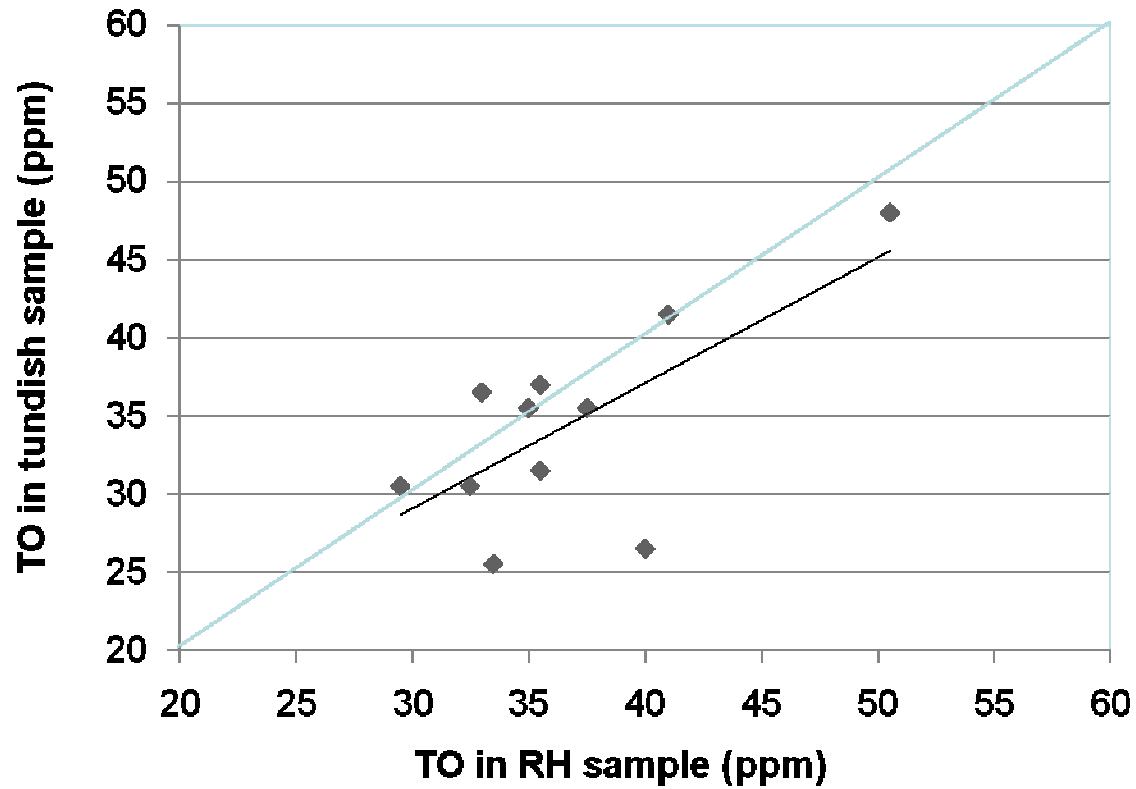
TO in RH using two types of sampler

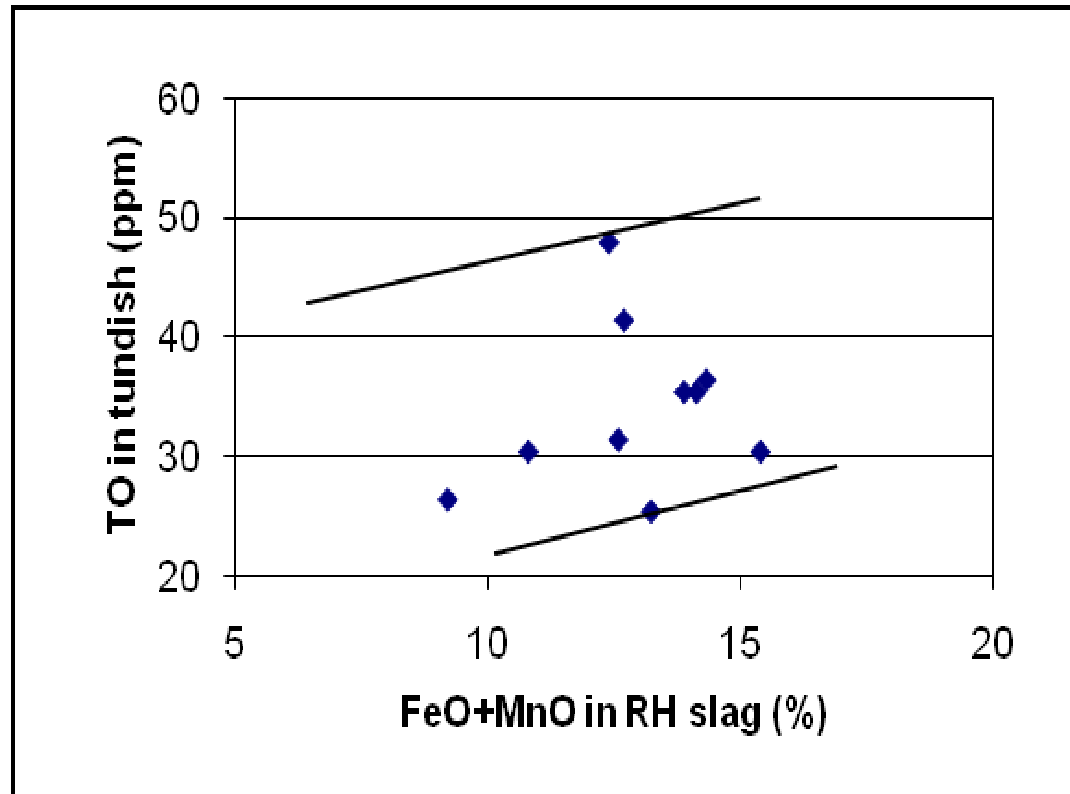
TO in tundish using two types of sampler



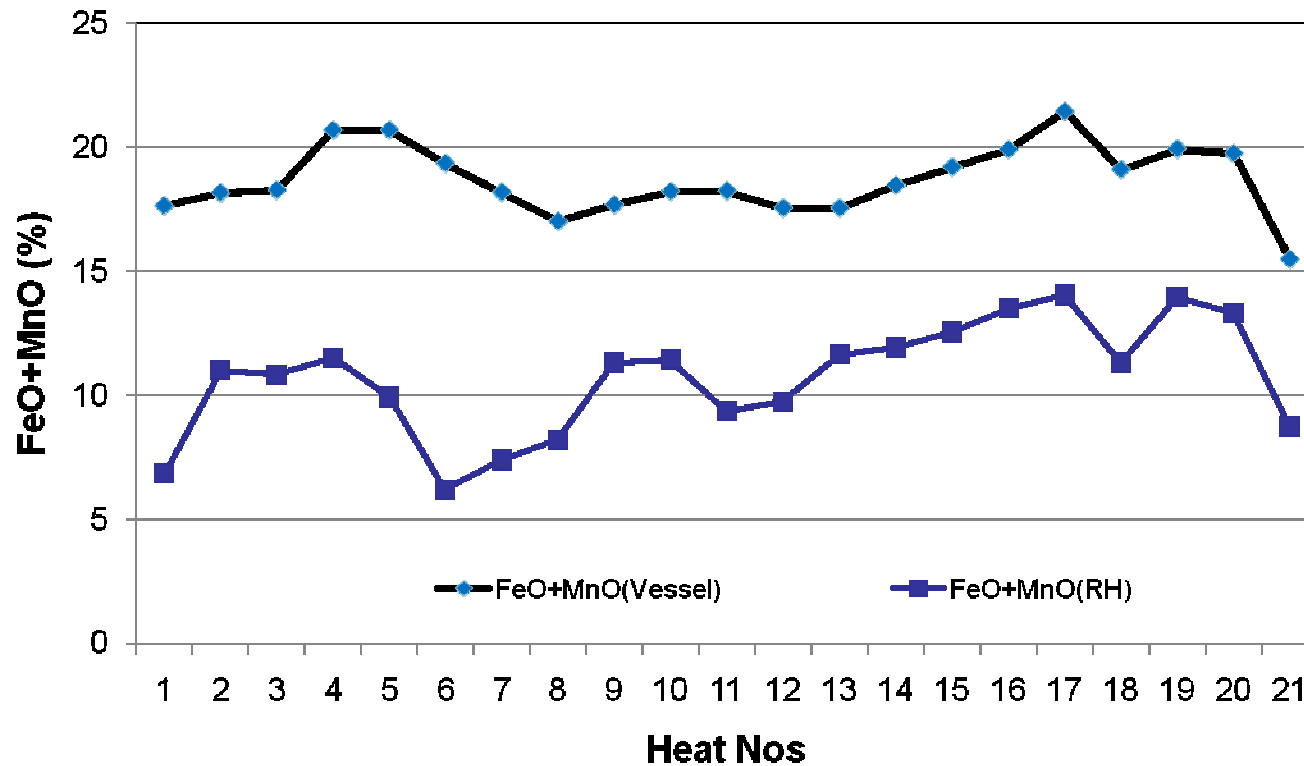


Total oxygen in steel at RH after treatment & at tundish

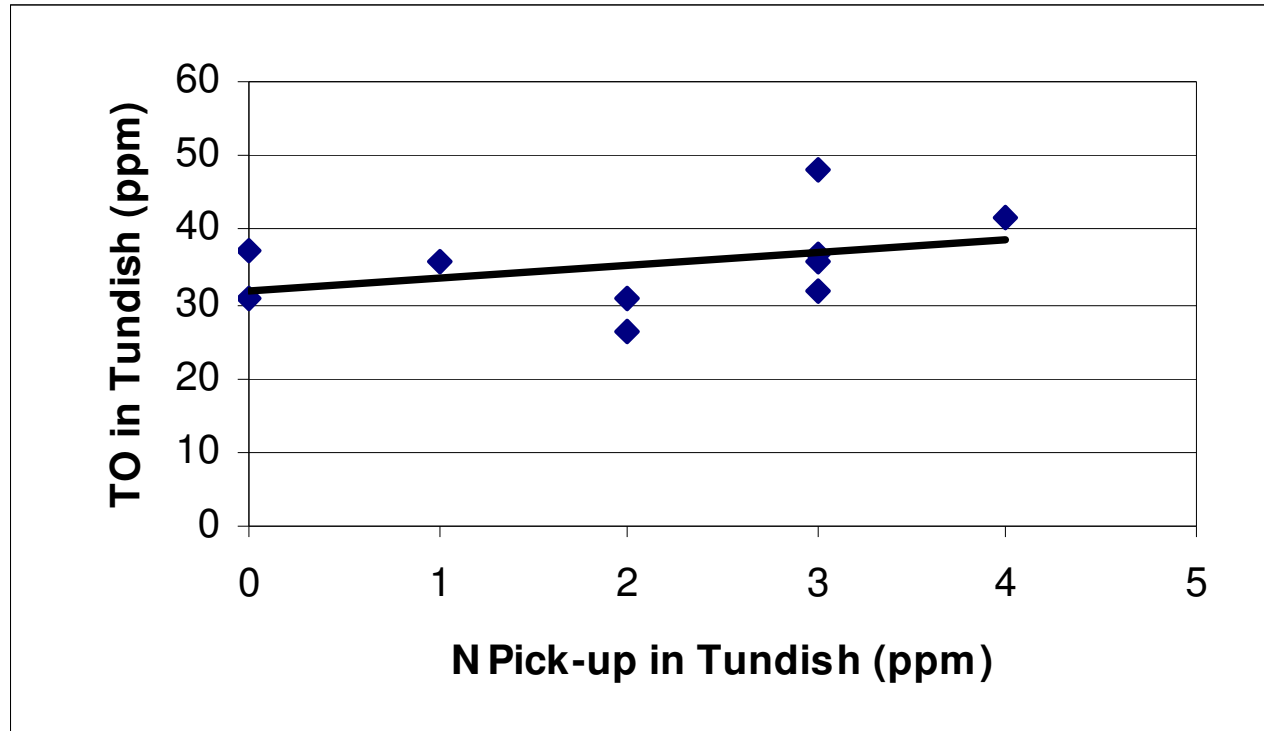




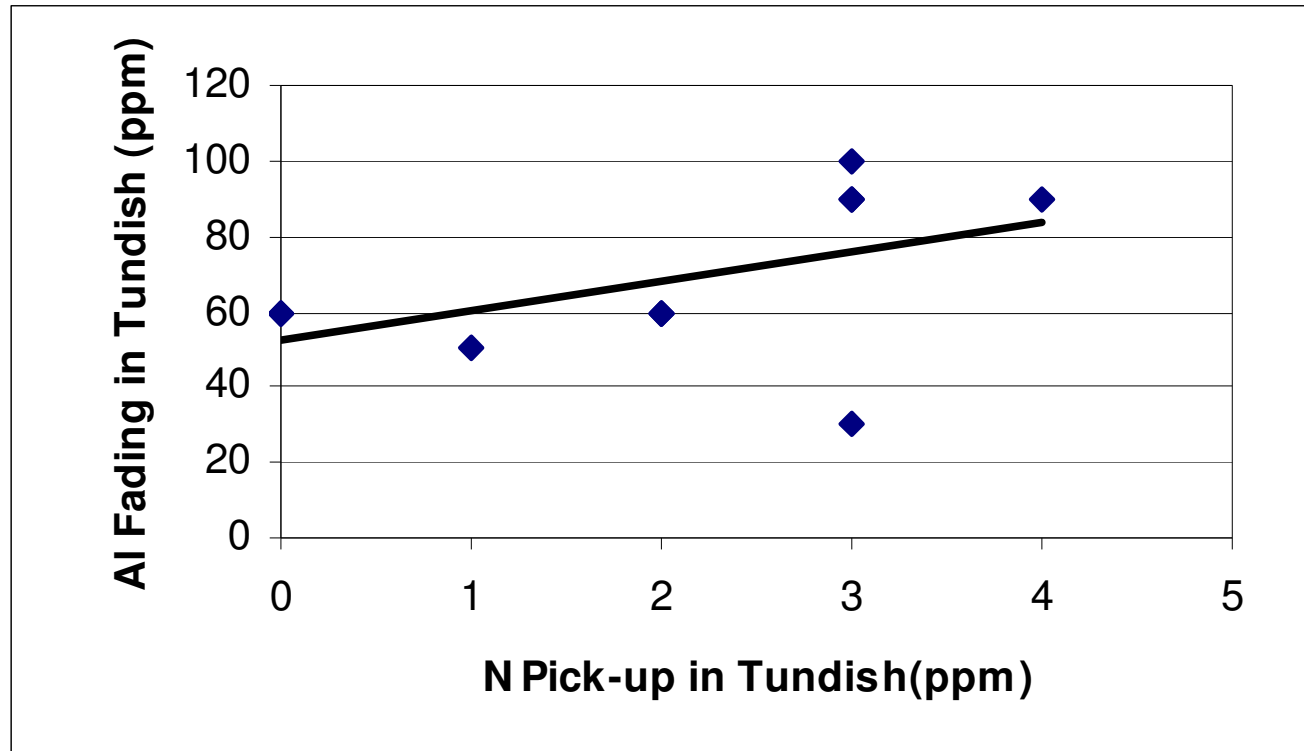
Effect of Conditioning on FeO and MnO in Slag



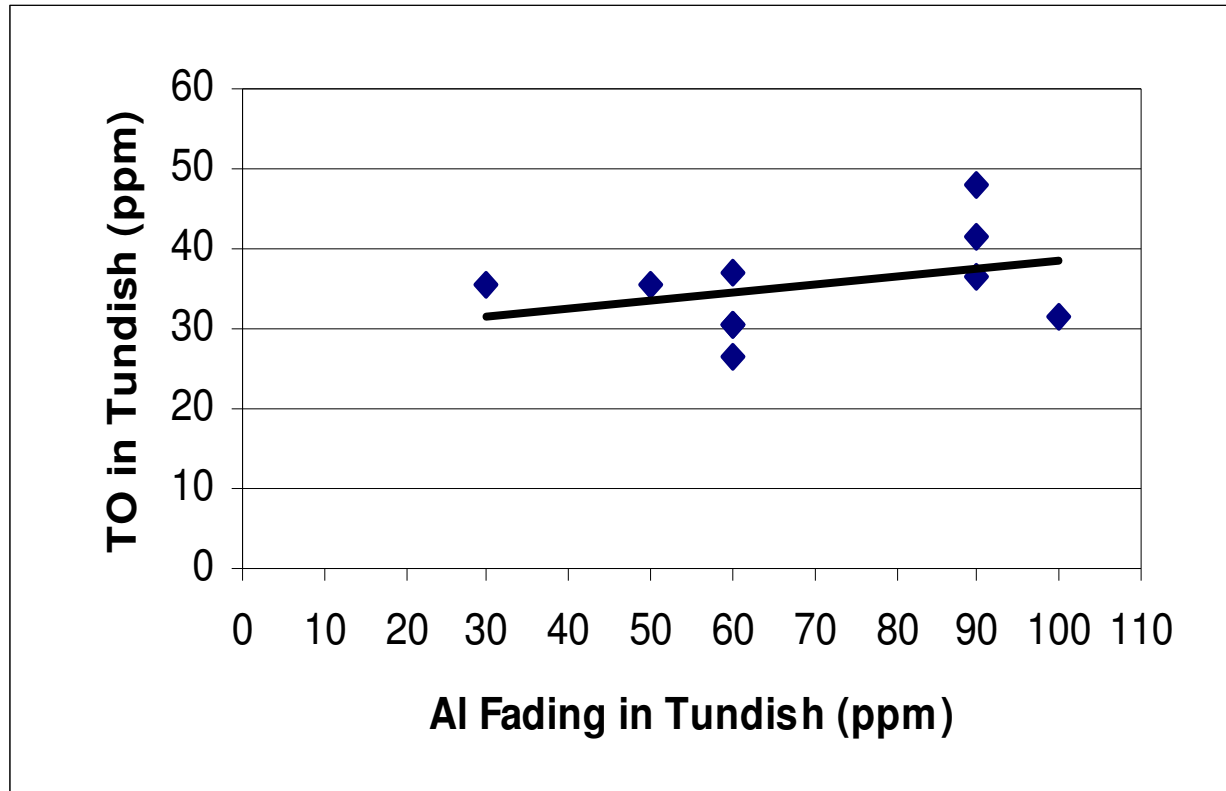
Total Oxygen and nitrogen pick-up in tundish



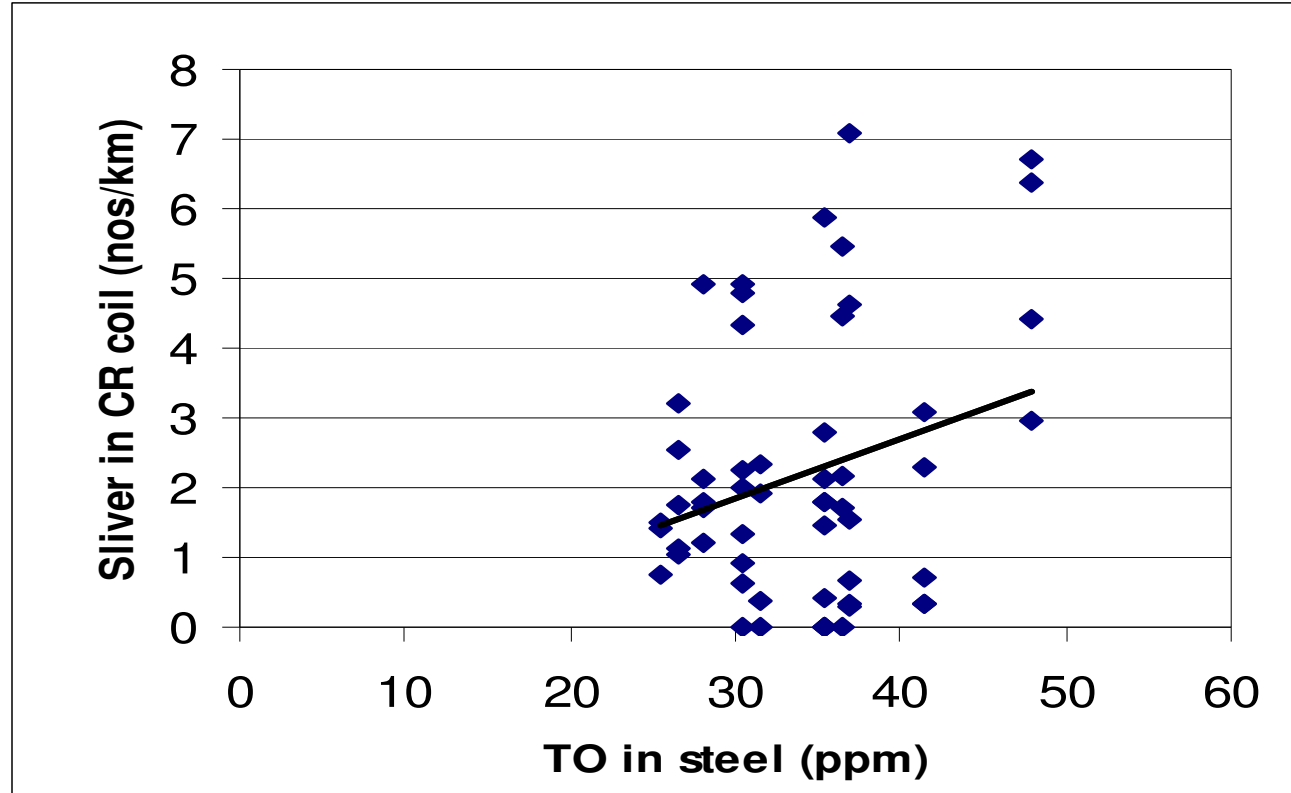
Nitrogen pick-up and aluminium loss in tundish



Effect of aluminium loss at tundish on TO



TO in steel and sliver in cold rolled coil

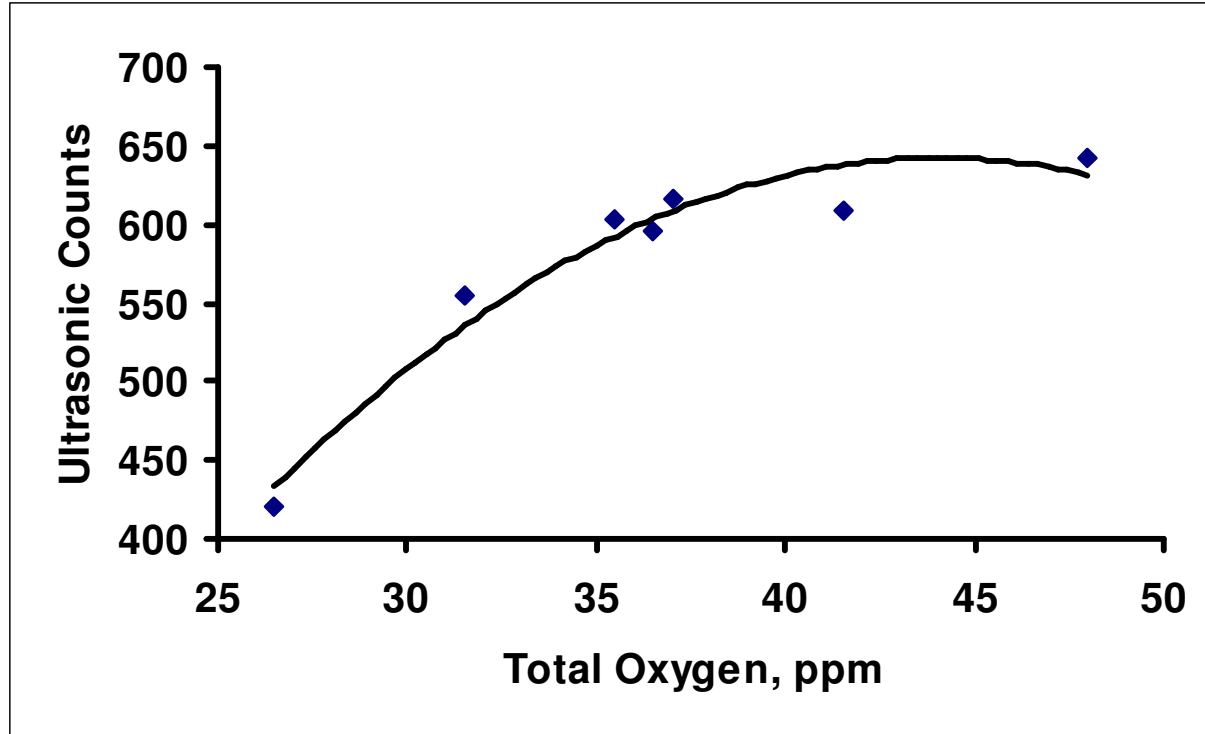


Assessment of Cleanliness Using Ultrasonic C Scan Image Analysis Technique

10 MHz, 15 mm diameter focused beam probe with amplitude threshold 1.1 to 1.2 a.u.

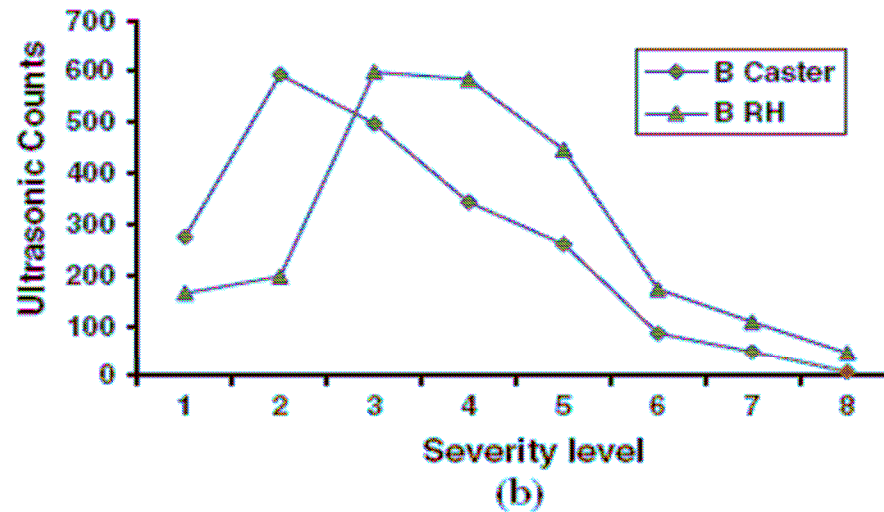
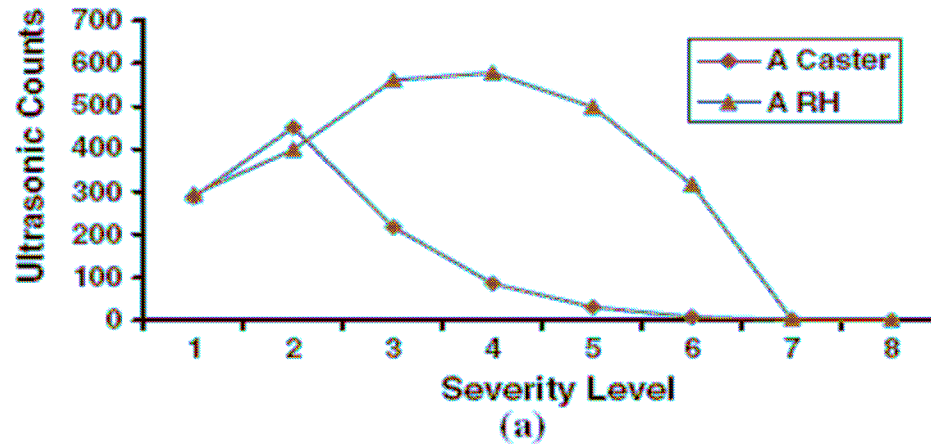


Correlation between TO in tundish samples and ultrasonic counts

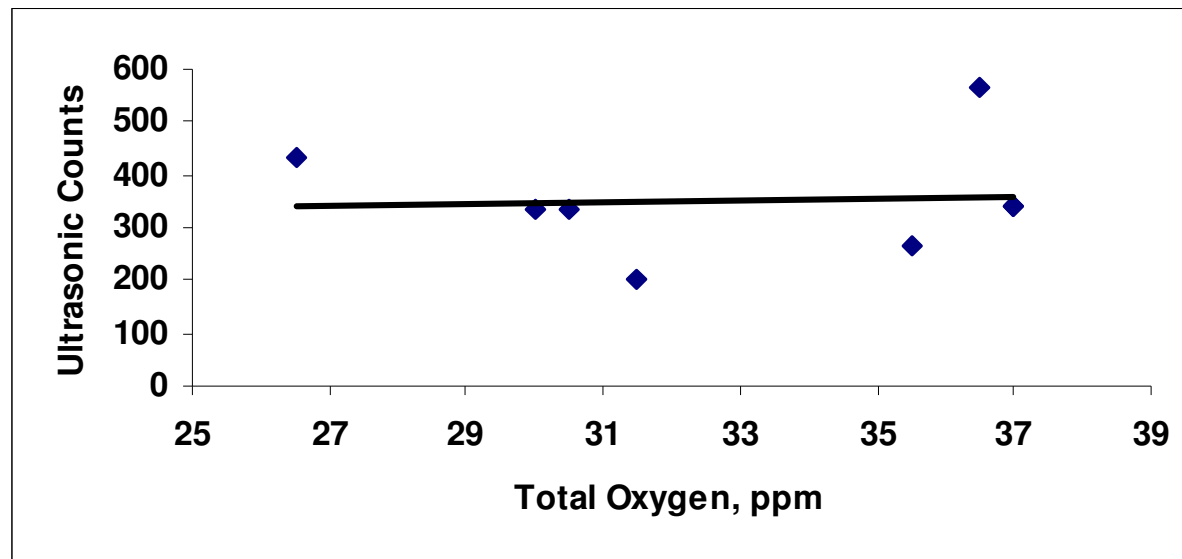




Ultrasonic Counts vs Cleanliness Severity Level in RH and Tundish Samples

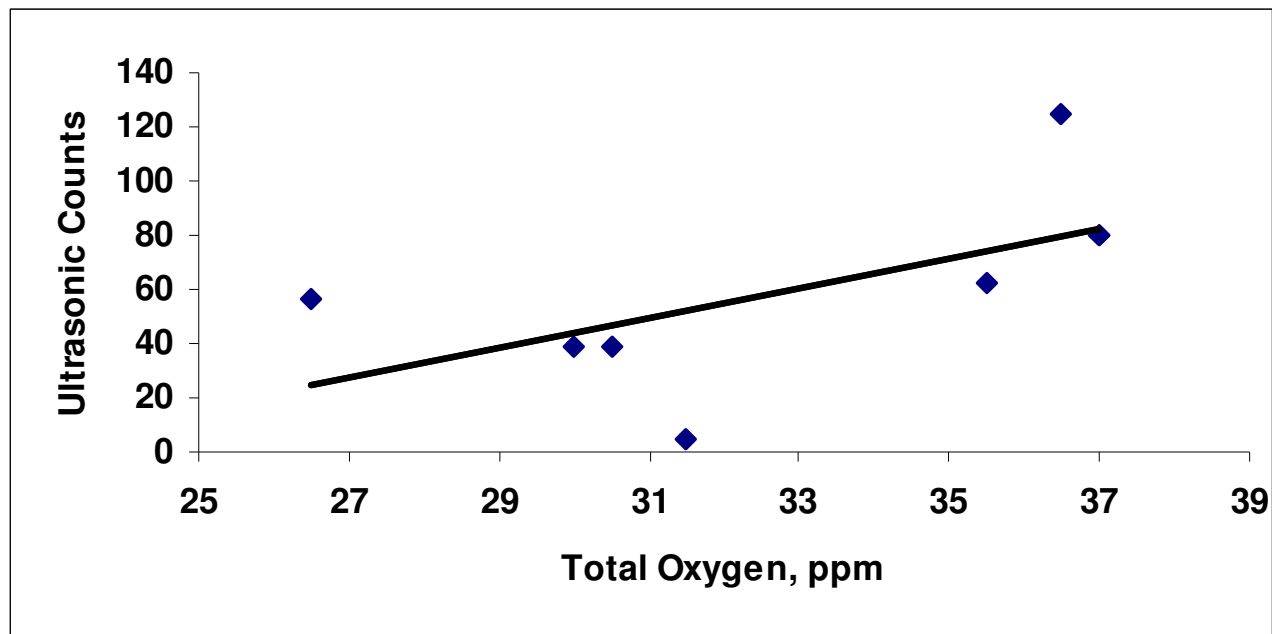


Relation between ultrasonic counts and TO for inclusion size 0.04 - 0.12 mm²



Not much variation in population of smaller inclusions

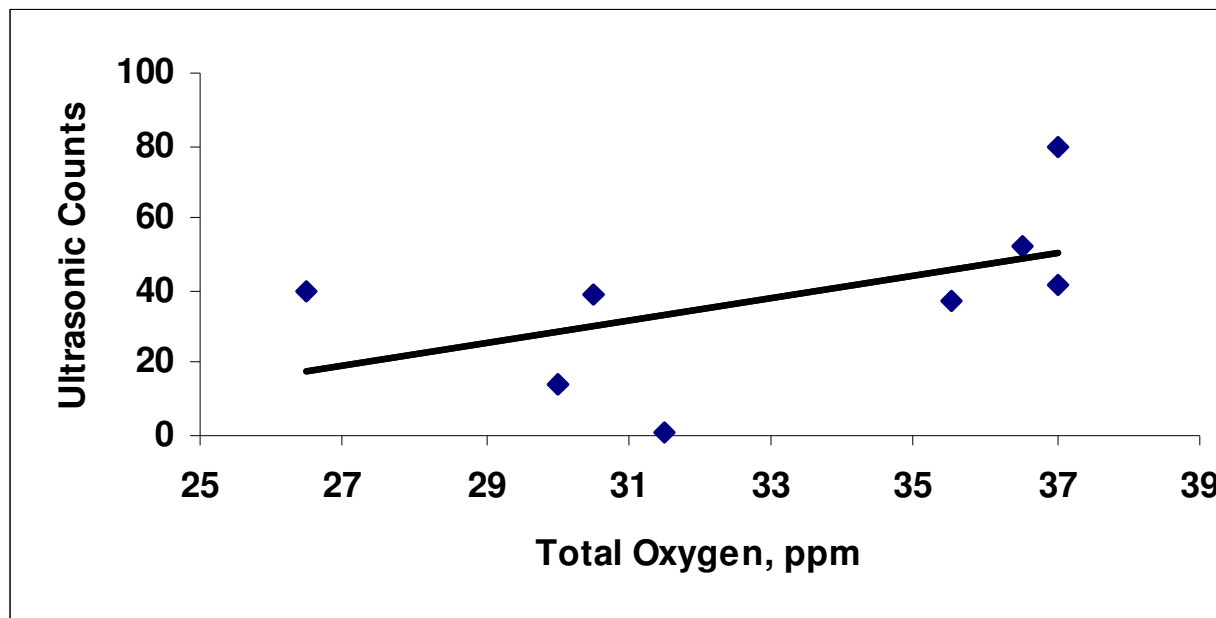
Relation between ultrasonic counts and TO for the inclusion size range 0.12 - 0.20 mm²



Increased level of TO is an indication of large size inclusions

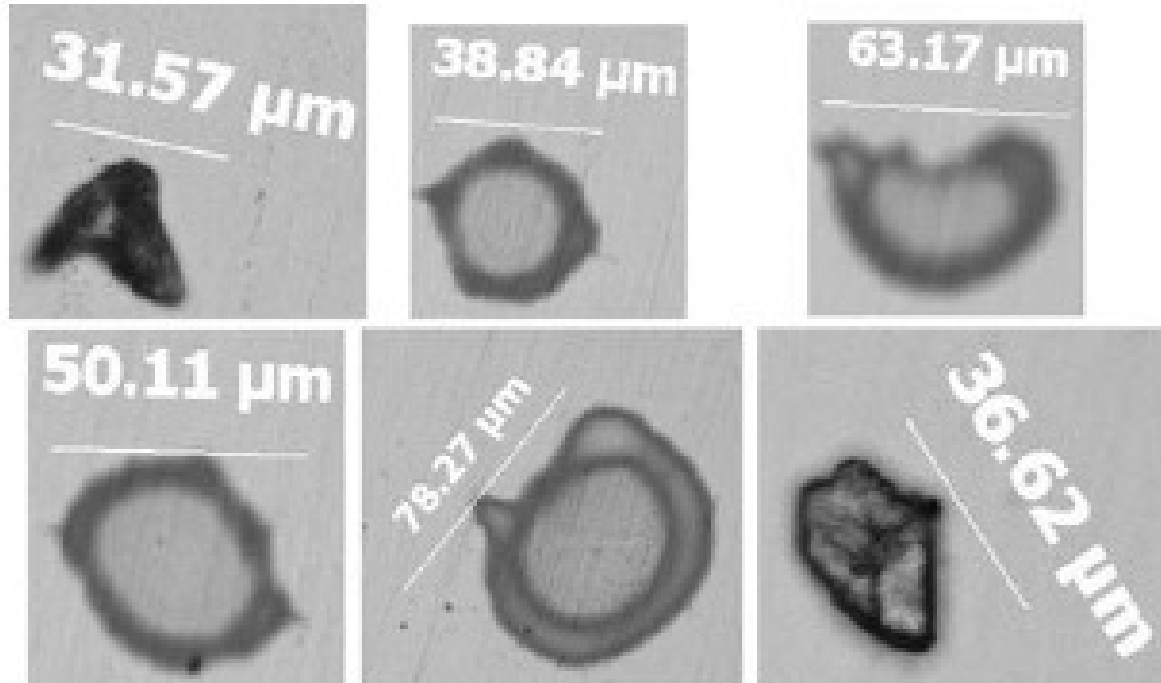


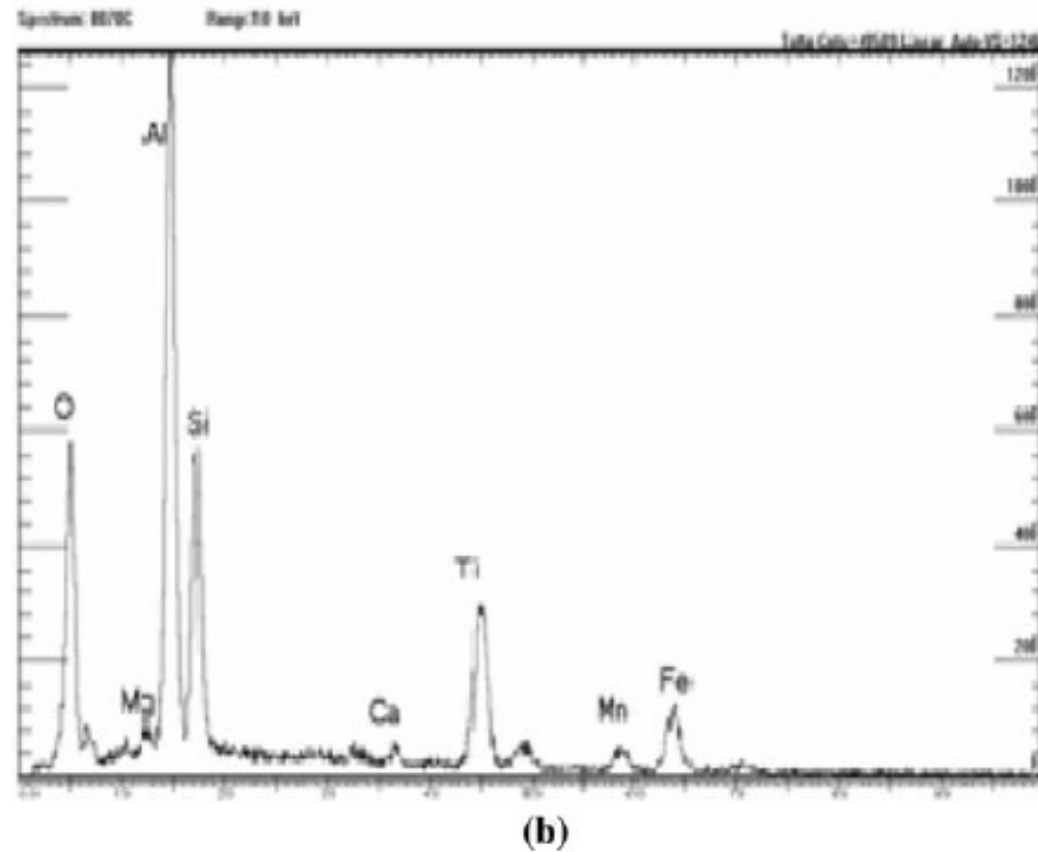
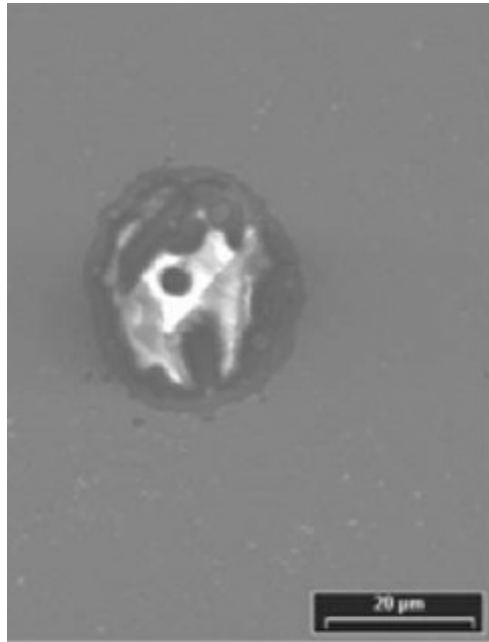
Relation between ultrasonic counts and TO for inclusion size 0.20 - 0.28mm²



Increased level of TO is an indication of large size inclusions

Some macroinclusions observed under optical microscope





Typical (a) SEM image and (b) EDS spectrum of a globular aluminosilicate inclusion



SEM-EDX results of typical inclusions observed in the samples

SampID	Inclusion size					
	<50 microns	Types of inclusion	50-100 microns	Types of inclusion	>100 microns	Types of inclusion
97588	yes	Alumina, Alumino silicate	yes	Calcium alumino silicate	Nil	-
97593	yes	Alumina, Alumino silicate	yes	Calcium alumino silicate	Nil	-I
97596	yes	Alumina, Alumino silicate	yes	Alumina	Nil	-I
97586	yes	Complex NMI	Nil	Nil	Nil	-I
97972	yes	Alumina	Nil	Nil	Nil	-I
97569	yes	Alumina, Calcium aluminate	Nil	Nil	Nil	-I

1. Two types of samplers used for TO measurement. Normal dual thickness sampler showed marginally higher TO values compared to special sampler. This indicates that if required normal sampler can be used for TO measurement with reasonable accuracy which will be effective with regard to time and cost
2. TO observed to be varied with processing stages. The study revealed an increasing trend of TO in tundish with increased TO in steel at RH Degasser
3. A correlation observed between TO in steel in tundish and occurrence of sliver in cold rolled coils

4. Within scatter some trend between reducible oxides such as FeO and MnO in RH slag and TO in tundish was observed
5. The relation between Al losses in tundish with TO indicated reoxidation during casting. The reoxidation due to air entrainment was also evident from nitrogen pick-up.
6. Ultrasonic method can serve as a useful tool in determining steel cleanliness. The ultrasonic evaluation revealed deterioration of steel quality with increased TO with regard to the extent and size of inclusion in steel



Thank You