CHAPTER 3

EXPERIMENTAL METHOD

Experimental methods to measure the air-gap are one of the best ways to know the transient air-gap size. Every method has its own limitations and advantages in finding the air-gap with high accuracy. Since the air-gaps are indirectly proportional to the interfacial heat transfer coefficient which controls the solidification rate and (microstructures) strength of the castings, it is essential to know the transient air-gap width with highest accuracy.

In the present study a new technique was developed to measure the transient average air-gap size.

3.1 METHODLOGY

Any two metallic surfaces, generally named as electrodes, separated by insulation, air or any other insulant or layers of insulating materials constitute a condenser. When voltage is applied across the electrodes, electrostatic energy may be stored in the system. When used for storage of energy, the insulation is better known as dielectric material. The ability of the dielectric material to store electro static energy is known as its “permittivity” or ‘dielectric constant”.
The capacity of a condenser depends on

(i) The effective area of the electrodes – capacity is directly proportional to the surface area of the electrodes.

(ii) Distance between the electrodes – capacity is inversely proportional to the distance between the electrodes and

(iii) Permittivity of the medium between the electrodes – capacity is directly proportional to the permittivity.

Cylindrical condensers such as cable or co-axial condensers are one among the other types of condensers viz. irregular, plate, spherical and parallel wire.

The capacitance of a cylindrical condenser, William H.Hayt. Jr. (2001), is defined as

\[ C = \frac{2\pi\varepsilon_0\varepsilon_r l}{\log_e(R/r)} \] Farad

(3.1)

where

\( C \) – Capacitance in Farad
\( \varepsilon_0 \) – Permittivity of air
\( \varepsilon_r \) – Relative permittivity of the medium
\( l \) - Height of the rings in meter
\( R \) – Radius of the outer ring of air-gap (inner radius of mould), in meter
r – Radius of the inner ring of air-gap (outer radius of cast), in meter
and (R-r) = air gap

Since capacitance is inversely proportional to the distance between
the electrodes, the air-gap that forms between the cast and mould, can reflect on
the charge of the condenser. Using a digital LCR (Inductance, Capacitance and
Resistance) meter, the change in capacitance can be known.

This change in capacitance can be converted into air-gaps. This
concept is used in this experiment to measure the air-gap which forms between
the cast and permanent mould.

3.2 LIMITATIONS

1. This concept can be applied on metals only i.e. between
cast metal and permanent mould.

2. Only an average air-gap width between the cast and mould
can be found

3. Air-gap at various locations of the profile can not be found

4. Individual movements of cast and mould can not be found
directly. But with a detailed analysis, it can be found.

5. Geometry of mould decides the success of this method.
Peripheral air-gap only in simple and regular geometry
casts can be found by this method.
3.3 EXPERIMENTAL SETUP

A mild steel mould of 54.88 mm ID, 75.68mmOD and 95.86mm height is placed in a stand with asbestos insulating rings at the top and bottom of the mould and a disc at the bottom to insulate the mould from the stand as shown in the Figure 3.1. Proper supports are arranged for safe position. A 10mm thick copper rod, placed at the center of the hollow part of the cylinder and a thin copper wire connected to the mould are connected to a digital LCR meter. A digital clock is arranged to provide time in seconds. Since there is no connection between the mould and the Cu rod, the LCR meter displays some capacitance. Photographs of the mould and the entire experimental setup are shown in the Figures 3.2 and 3.3.

![Figure 3.1 Schematic diagram of the experimental Setup](image-url)
Figure 3.2 Mould Setup

Figure 3.3 Experimental Setup.
The mould is wetted with SAE40 oil and dusted with bentonite powder to act as a separator between the cast and mould. The mould chamber is preheated to a temperature around 573 K to evaporate the oil coating and it was left for few minutes. Now the molten metal is poured into the mould carefully without spilling on the mould and stopped when the mould is full. This causes the Cu rod to get immersed into the cast metal. Now the molten metal and mould have perfect contact between them, the LCR meter displays some inductance. As the solidification starts progressing, the cast metal starts shrinking and the mould starts expanding, resulting an air-gap forms between them. This will be displayed in the LCR meter as capacitance. The LCR display shuttles between the inductance and capacitance, showing the initiation of the detachment of cast from the mould. Once the cast gets detached fully from the mould, indicating the formation of air-gap, the LCR meter display gets settled in capacitance.

Initially the capacitance will be at a high value, due to the fine air-gap formed and as the solidification progresses, the solidification shrinkage of the molten metal and the expansion of the mould due to the heat transfer from the cast to the mould, increases the air-gap resulting a decrease in capacitance.

The capacitance settles at a value without much variation shows the end of air-gap expansion. The expanded mould will return back to its original size when the cast and mould reaches the room temperature. The whole experiment is video recorded for the purpose of noting down the time and the corresponding LCR display. The experiment is repeated for Al 6wt%, Si alloy and Al 13wt% Si alloy with top of the mould closed and opened conditions.
From the capacitance, air-gap values are calculated. The LCR meter display is termed as measured capacitance. The LCR meter used in this experiment is Scientific Mes-Technic make and its model number was HM 6018. It has a sensitivity of unit ohm (\(\Omega\)) resistance, pico Farad (pF) capacitance and micro Henry (\(\mu H\)) inductance.

3.4 STAGES IN DEVELOPMENT OF AIR-GAP

The development of air-gap between the cast and mould occurs in three distinct stages as given below:

i. Detachment of cast from mould indicating the initiation of gap. Onset of this stage is indicated by the oscillation of LCR Meter reading between inductance and capacitance.

ii. Formation of perfect and continuous air-gap and its expansion. In this stage complete detachment of cast from mould occurs and subsequently the air-gap expands. Onset of this stage is indicated by stabilized capacitance reading in LCR Meter.

iii. Attainment of maximum air-gap width. The maximum air-gap width is observed when the shrinkage of the cast and the expansion of the mould become insignificant. Attainment of this stage is indicated by the constant value of capacitance in LCR Meter.

3.5 CALIBRATION

Width of air-gap is a cumulative of shrinkage of cast, expansion of mould and thickness of bentonite coating on the mould inner surface. The air in the air-gap is normally a mixture of gasses evolved from the asbestos insulators,
oil coating and the bentonite powder coating. This mixture of gases may have a different permittivity value than that of the air at various temperatures. These parameters may cause a difference between the calculated capacitance, obtained from the actual dimensions and the measured capacitance, obtained from the LCR meter. So to have a co-relation between the calculated capacitance and measured capacitance and to extrapolate this relation, calibration is done.

The casts are measured and their average heights and diameters are noted. Mild steel solid cylinders of various diameters at the heights of the casts are prepared. The solid cylinders are placed inside the mould, like the experimental setup, and their capacitances are measured on the LCR meter at the room temperature. For their known air-gaps, capacitances are also calculated.

Similarly for the average diameter of the casts, the measured and calculated capacitances are found and tabulated. Calibration equations are formed for all the experiments. With the help of the calibration equations, for any measured capacitance a corresponding value of calculated capacitance can be found.