Chapter 2
Modeling of DC Attraction Type Levitation System

ABSTRACT

For the successful implementation of any DCALS, the operating air-gap plays a vital role. Selection of operating air-gap is important to develop a model of any DCALS. The operating air-gap between the pole-face of electromagnet and the object cannot be made arbitrarily too small or too large for many reasons. A very small operating air-gap is not good from safety point of view while there should be enough margins so that, in worst case, the electromagnet does not hit the object. It is always advantageous to select the operating air-gap in between lower and higher gap zone (medium gap). Nevertheless, the final selection of the air-gap depends on the particular system, the type of application, and the payload.

INTRODUCTION

For the successful implementation of any DCALS the operating air-gap plays a vital role. Selection of operating air-gap is important to develop a model of any DCALS. The operating air-gap between the pole-face of electromagnet and the object (Figure 1) cannot be made arbitrarily too small or too large for many reasons (Banerjee & Bhaduri, 2009). A very small operating air-gap is not good from safety point of view while there should be enough margins so that, in worst case, the electromagnet does not hit the object.

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In most DCALS the inductance variation with air-gap (between pole face of magnet and surface of object) shows three clear zones. Figure 2 shows typical inductance profile of a DCALS. It is seen that in the lower gap zone the inductance varies rapidly, almost exponentially with the gap. In the medium gap zone the inductance variation is inversely proportional to the gap. The inductance does not vary much in the higher gap zone and remains almost constant. Due to high L/R ratio, it is more critical to have a faster control of electromagnetic force in low gap. The large variation of inductance causes wide change in levitated system parameters and the robust controller design becomes a difficult job in low gap. In the higher gap zone the system parameters do not vary widely because of very slow change in the coil-inductance. So robust controller design may be easier in the higher air-gap zone. But in this zone the required current for levitation is very high. The typical characteristic of coil-current versus operating air-gap for a levitated system is shown in Figure 3.

So, in terms of energy consumption the selection of high gap is not desirable. The EMI problem (Boldea, 1985) is much more pronounced in the high gap zone due to large current flowing through the magnet. Moreover, the high value of coil-current becomes a major constraint in the design of actuator, power amplifier and controller. In general, the size of actuator and power amplifier depends on the size of payload. But for a small prototype where the load requirement is supposed to be small, the size of actuator and power amplifier is influenced by the selection of the operating gap. In the case of high current one easy solution is the use of heavy gauge copper wire in actuator and more number of switches in parallel in the power amplifier. But that essentially increases the EMI problem in the control circuit. Selection of the position sensor becomes critical for measuring a large air-gap. The inductive type proximity sensor made by “Contrinex AG Industrial Electronics” of Switzerland is capable of measuring higher air-gaps. However, in electromagnetic applications, this type of sensor suffers from some disadvantages. When a switching amplifier is used, the switching noise from the magnetic suspension system can strongly couple with the probe signals. All these effects get enhanced in higher gap due to the large coil-current. For better stabilization of such an inherently unstable system, the controller mostly used in electromagnetic levitation is PD/Lead type. These controllers are more prone to be affected by noise signals.