Abstract
The efficient and accurate operation of X-ray machines is paramount in various industries. This paper delves into the critical aspect of understanding X-ray machine parameter settings, aiming to provide insights into the complexities involved in optimizing these settings for optimal imaging quality. The paper explores the fundamental parameters that govern X-ray production, such as tube voltage, current and exposure time. It examines the intricate interplay between these parameters and their impact on image quality and material penetration. By comprehending these relationships, an X-Ray operator can make informed decisions to balance the need for quality imaging.

Keywords: Tube Voltage (Kv), Tube Current (mA), X-ray, exposure time, non-destructive testing (NDT)

Introduction
Details of all functions on a common X-Ray Controller:

- **Tube Voltage (kV):** Tube voltage determines the energy level of the X-ray photons produced by the X-ray tube. It controls the penetration ability of the X-rays through the subject and affects the image's contrast. A higher kV results in X-rays with greater energy, which can penetrate thicker tissues more effectively, but might reduce image contrast. Lower kV produces X-rays that are more readily absorbed, creating higher contrast images suitable for visualizing denser structures like bones. Proper selection of kV is essential for obtaining diagnostically useful images.

- **Tube Current (mA - Milliamperage):** Tube current refers to the number of electrons flowing from the cathode to the anode in the X-ray tube per unit of time. It controls the quantity of X-rays produced, which directly affects the image's brightness or exposure. Higher tube current generates more X-rays, resulting in a brighter image. Adjusting the tube current is important for optimizing the exposure to avoid overexposure (which can lead to excessive radiation dose) or underexposure (which can result in poor image quality).

- **Focal Spot Size (Focal Point):** The focal spot size refers to the area on the anode target where the electron beam strikes to generate X-rays. As explained earlier, the size of the focal spot affects image resolution and heat generation. A smaller focal spot provides better image detail but generates more heat, while a larger focal spot reduces heat buildup but may result in lower image resolution. The choice of focal spot size depends on the imaging requirements and the balance between resolution and heat management.

  Function of Focus: The primary function of the focus in an X-ray machine is to control the size of the X-ray beam emitted from the X-ray tube. The smaller the focal spot, the sharper the image detail that can be captured. However, there's a trade-off between image detail and the amount of heat generated. Smaller focal spots can heat up quickly, potentially damaging the anode. Larger focal spots produce a broader beam, which can reduce heat buildup but results in lower image resolution.

- **Exposure Time (Timer):** The exposure time, controlled by the timer, determines how long the X-ray tube produces X-rays during a single exposure. It plays a crucial role in regulating the total radiation dose delivered to the patient or object. Longer exposure times result in more X-rays and higher doses. The timer helps prevent overexposure and allows for proper exposure of various body parts or objects, taking into account their density and thickness.
**Aim of Article:**

Whenever the job changes (thickness, material etc.) we need to re-set the X-ray parameters to get good quality radiographs. If the inside parameters are fixed (source to job distance, focal point, job to film/recording device distance and film type etc.), the tube voltage and tube current need to be adjusted accordingly to increase or decrease the exposure time.

In this article I will try to explain X-ray tube voltage, current and time. The article uses small marble, gun and missile to explain KV and the number of persons/quantity of small marbles, guns and missiles used to explain MA.

**X-RAY system Controller**

**Understand Relation between kV (tube voltage) and mA (Current) by below example**

**Step-1**

Tube voltage (KV): KV you can say that it is the power of X-ray machine. For example, there is a wall that has holes in it and is covered with cardboard. Now suppose you have small marbles and someone instructs you to find a hole in the wall hidden behind the cardboard with the help of these small marbles. Because the power of small marbles is not enough to penetrate the cardboard and trace the hole in the wall, it is an example of low KV.

Now suppose the instructor tells you to take an extra person with you and find holes in the wall with small marbles. So this is an example of increasing mA. Now since your power is the same you still can't detect holes in the wall so increasing the mA (amount or number) is useless if you don't have enough power (KV).

**Step-2**

Now instead of small marbles, if you try to find a hole in the wall by firing a gun at a wall covered with cardboard, you will be able to easily find a hole in the wall by penetrating the cardboard. Basically in this step you increase the power (KV only). So once you have enough power (KV) you can scan the wall more quickly for all possible holes by just increasing the numbers (mA). Increasing mA means you can increase the number of guns or persons. You can fire a gun with both hands or multiple people can shoot at the wall at once. By doing this we can reduce the time effectively.

**Step-3**

Now if instead of a gun, you try to find a hole by firing a missile at a wall covered with cardboard, you will not be able to find a hole in a wall covered with cardboard. Wall and cardboard are the same for missiles and a missile will easily penetrate a wall and make a big hole. So in this case also you will not get holes in the wall which we initially covered with cardboard. This is an example of high power (KV) and now if you increase the number of missiles and manpower (mA) it doesn't matter.

**Summary:**

From the analysis of all three steps it is clear that first of all accurate tube voltage (kV) is required, which should be within the range/window. Once the tube voltage (kV) is set the role of tube current (mA) becomes important

and by increasing the tube current the exposure time can be reduced effectively. If tube voltage is not in range then tube current has no role and it is very clear from analysing step number 1 and 3. Now once you have your tube voltage and tube current final and only the exposure time needs to be changed. Exposure time in depends on various factors including source to job distance, focal point, job to film/recording device distance and film type etc.

**Conclusion:**

A comprehensive understanding of X-ray machine parameter settings is crucial for achieving optimal imaging quality and effective non-destructive testing (NDT) in various industries. The intricacies of X-ray machine parameters, focusing on tube voltage (kV), tube current (mA), and exposure time. Through relatable examples involving marbles, guns, and missiles, the article highlights the vital role that accurate parameter settings play in obtaining diagnostic-quality images.

The analogy presented in the article vividly illustrates the importance of balancing tube voltage and tube current. Just as the power of marbles, guns, and missiles determines their ability to penetrate barriers, the right combination of kV and mA is essential for achieving the desired level of image quality. The article emphasizes that an appropriate tube voltage is the foundation, enabling effective penetration through the material under examination. Once this foundational parameter is set, tube current can be adjusted to optimize the exposure time, reducing it while maintaining image quality. However, if the tube voltage is not within the optimal range, even increasing the tube current cannot compensate for the lack of penetrating power.

Furthermore exposure time in conjunction with factors such as source-to-job distance, focal point, and film type. These additional considerations contribute to the comprehensive understanding necessary for precise NDT outcomes.

In essence, the insights provided in this article emphasize the interdependence of X-ray machine parameters and their impact on image quality, radiation dose, and efficiency. By grasping the relationships between tube voltage, tube current, and exposure time, X-ray operators can make informed decisions to achieve accurate results while managing radiation exposure. This knowledge not only enhances the quality of non-destructive testing but also contributes to safety, efficiency, and the overall success of various industries reliant on X-ray technology.

**References:**