Assessment of an Tentative Novel Body of X-Ray tube in order to Decrease the Applicability Limitation in Medical Practice

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ABSTRACT

The output of X-ray, especially in the field of required energy for diagnosing the disease is very low (in diagnosing lamps, it is less than 1%). In this kind of lamps the rest of the electrical energy is transformed to heat. This considerable amount of heat induces a myriad of too many limitations in choosing higher levels of radiation, particularly in specialized techniques. This process is the outcome of X-ray generating mechanism; thus, one of the proper solutions to reduce the limitations caused by generating high heat is enhancing the cooling rate in these lamps. In this project, the design and alloy of the framework, surface and the substance were altered in a manner whereby the cooling rate increases or heat accumulation in lamps decreases. This surface was designed in the shape of a two-part disc with wings whose substance is the same as the framework. The substance of the framework is made of an alloy of copper and chromium. The disc shape of the framework and its aerodynamic compatibility further expose its contacting surface to the air. This contacting surface can be expanded to 10 times more than the ordinary frameworks. The heat conductivity coefficient of this alloy is approximately 220 w/ mk, which in comparison with the heat conductivity coefficient of the ordinary lamps framework, being about 10, is 22 times more. The results of the tests reveal that the cooling rate of this framework is 10 times (or 1000%) more than the ordinary one. This process reduces the limitations of choosing radiation factors with the same proportion.

Key words: X- ray; output of X lamps; X- ray generator.

INTRUDUCTION

Basically, the source of generating X-ray is the kinetic energy of accelerating electrons. This mechanism occurs in a manner whereby a tiny percent of this energy is transformed to heat.

In X-ray generator lamps, the required energy for reducing and accelerating the electrons or increasing their kinetic energy, for transforming them to X-ray, is provided by the electrical energy. In this kind of lamps, there are 3 basic factors: kilo volts pick (the maximum voltage of two ends of the lamp). This factor specifies the penetration power or the ray quality.

Mil-ampere: this factor, define the number of electrons or the number of photons or the ray intensity.

Time: this factor, multiplied by intensity, denotes the quantity of the ray.

Transforming a substantial amount of electrical energy to heat energy (99%) is a part of X-ray generating mechanism, therefore, the limitations of generating more intensities, which are functional for diagnostic, therapeutic and industrial cases, are the lack of possibility to choose higher levels of radiation.

Selecting the higher levels of radiation necessitates an increase in the cooling rate. In fact, the slow cooling rate of these lamps induces heat accumulation, spot melting of anode (the target substance of dynamic and energetic electrons). Scattering of ray, and then ultimately makes the lamp out of work.

The significant issue, on which this project is based, is to alter the geometrical design and the substance of the framework of the X- ray generator lamp in a way that the cooling rate increases or the heat accumulation in lamps decreases.

Hence, the elements which reduces the cooling rate in the framework of X-ray generators or increases the accumulation of heat in lamp should be investigated.

These elements are:

1- The size of the effective area of the framework. As the effective surface of the framework is larger, the heat will be applied to a larger area. In this vein, the quantity of radiation from a larger surface is more than the smaller one. (The intensity of radiation in a certain substance is related to the unit of area). [1-4]

2- The substance of the framework: as the conductivity coefficient raises, the heat accumulation in lamp will be less, since it spreads faster in the surface of the framework and due to being exposed to air molecules, in the condition of existence of air current, the cooling rate will remarkably rise.

Moreover, substances of the surface should be chosen the high melting point. They should be resistant to sudden variation in temperature as well.

Heat accumulation in lamp and lack of enough fast cooling rates, lead to these difficulties:

- Scattering of X-ray and output reduction: gradual spot melting of anode surface that is the result of high heat of lamp and lack of suitable cooling rate, produces some microscopic wrinkles on the surface of the anode and attracts an enormous number of produced X photons scattering them out of their hatches. This process notably, results in a reduction of output[2-5].

- The Surface evaporation of anode: the tungsten of anode gradually evaporates owing to the high heat and settlement of the internal surface of the lamp.

- This metal layer changes the lamp to a mirror and as a new electrode, departures the electrons, and lowers the exhausting intensity of the ray and reduces the output. [3-6]

- Very high expense of production: due to generating extremely high heat, the various parts of the lamp such as ball bearings, rotor and stator, anode shaft and cathode framework should be made of high heat- resistant substances; these kinds of substances have a low conductivity coefficient and higher production expenses[5-6].

The framework of ordinary lamps is made of glass and some kinds of insulator oil encircle this framework and then there is a cast iron container to hold the oil and glass lamp. The conductivity coefficient of the glass is 1, this coefficient in oil is 0.1 and in cast iron is about 20; thus, average of them is about 10[7-8].

(According to the international system, the unit of conductivity coefficient is W/m × Kelvin). This coefficient is relatively too low; however, due to the problem of high voltage of the lamp, the substance of the framework is made of glass. If a suitable solution for this problem had been reached (the problem of high voltage), some other substances such as metals which have relatively high conductivity coefficient, would have been used so far. This solution has been proposed and tested in the presented design. [12]

The producer companies of X-ray generators, because of these difficulties, appointed some limitations for their customers. For instance, in the therapeutic lamps of Gal May corporation, which is one of the latest generation of producers of this kind of lamps, in the condition of 300 kilo volt pick, 10 mil-ampere can be selected with the utmost performance, and for higher intensity, the voltage should be reduced. For example, the intensity for 15 mil-amperes can be 200 kilo volt pick at the maximum amount. These limitations also prevail in diagnostic functions such as angiography; moreover, in industrial functions of X-ray, protection and safety increase the limitations[9-10] .

These limitations are the results of the limited cooling rate in these lamps, on the account of the reasons discussed.

According to the same reasons, in designing the framework of X-ray generator lamps, the high heat, which is generated during its operation, is very significant and should be contemplated. Since the output of generating X-ray is originally low and in this kind of lamps, most of the electrical energy is transformed to heat and heat production is inevitable, therefor, most research units of big companies concentrate on approaching the problem of cooling system[11-13] .

The research center of the Siemens Company, which is one of the producer companies of X-ray generator lamps, recommends two new designs for increasing the cooling rate of the framework of the X- ray generator lamps.
The summary of these designs are discussed below:
- Designing and producing the X-ray generator pipes with furrowed zigzagged bearings. These furrows are made in the framework and their existence reduces the contacting surface of ball bearings with the framework and as a result, less heat is transmitted to the ball bearings.
- The ball bearings are the damageable parts of the framework. This design renders them more durable and also brings the possibility of generating higher intensity of X-ray. This system provides the possibility of increasing the intensity by 15%. [10].

MATERILS AND METHODS

As presented in Figure 1, in this framework design, new shape, designing and substance are proposed for X-ray generators. This framework is in the shape of a two- parts disc and several fan- shaped plates which are made of the same substance as the frame work. The framework is made of an alloy of copper and chromium, the aerodynamics and the basic shape of the framework collaborated by air flow increase the contact surface with air, which is 10 times more than the ordinary framework. The melting point of this alloy is 1200 C; however it is very resistant to heat (it has high mechanical resistance and does not flake). The coefficient of heat conductivity of this alloy is 220 w/m-Kelvin and in comparison with the same coefficient of the framework of ordinary lamps, which is approximately 10, is 22 times more.
To construct the experimental sample of this framework with a new design and substance, the following technical stages were executed:
- The metal alloys which have high heat conductivity, medium mechanical resistance and melting point of approximately 1500 C, have been identified by consultation with metallurgy experts.
- Considering the estimation of conducting surface, the heat transforming rate and inertia against vacuum, several initial designs were provided and after consulting with a solid designing mechanic, the most suitable one was selected.
- The steel frame was made according to the specific voluminal sample being made of polyvenilbuthyral.
- The exactness of the steel frame was determined by the micrometer and the spherometer.
The initial framework was casted by the steel frame which was made of a copper and chromium alloy.
- The surface polishing, considering the prevention of surface evaporation, specially the internal surfaces, was accomplished in vacuum and high heat.
Micro grinding of the holes for the entrance of electrodes and installation of hatch and collimator were performed by CNC machines and laser grinding machines.
- The internal surfaces were separately polished.
Adjoining parts were adjoined by the specific alloy welding method.
The firmness quantity, water resistance and flatness of edges were verified by the digital radiographic machine in the laboratory of the radiology group of the paramedical college.

RESULTS

The produced framework was heated by a blower torch, which works with gas and produces high heat in 10 minutes and its temperature was immediately measured by a contacting thermometer of laboratory of Tiran chemistry company (until 1000 degree). Afterwards, it was put in an environment with a temperature equal to the normal room, and its cooling rate was measured. Both frameworks were precisely heated equally since the temperature directly affects the cooling rate.
This measurement was repeated 3 times and the average of cooling rate to about 50 C was defined, and in this new framework, it was 19.23 degree per second. However, the cooling rate in framework of the ordinary lamps, used for high intensities, was approximately 1.9 degree per second. These mentioned experiments indicate that the cooling rate of the new framework is 1000 percent or 10.12 times more than the ordinary one. In the next stage, the stress resistance of the framework was measured by tachometer. The same stages were accomplished for the ordinary lamp framework, and no difference in stress resistance was observed.

Figure 1. The shape of new metallic X-ray tube in this study.

Figure 2. Internal lacuna of new metallic X- ray tube in this study.

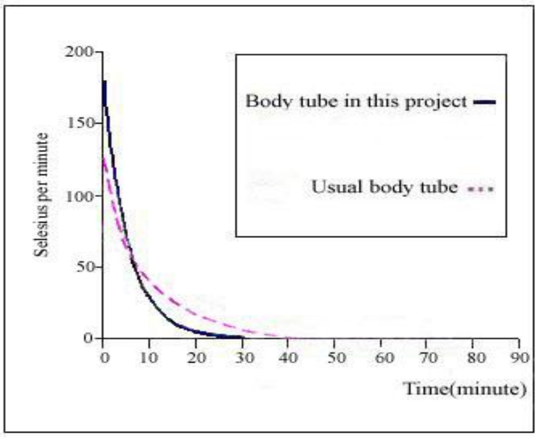

Figure 3. The time of heat reduction in usual Tube and in this project

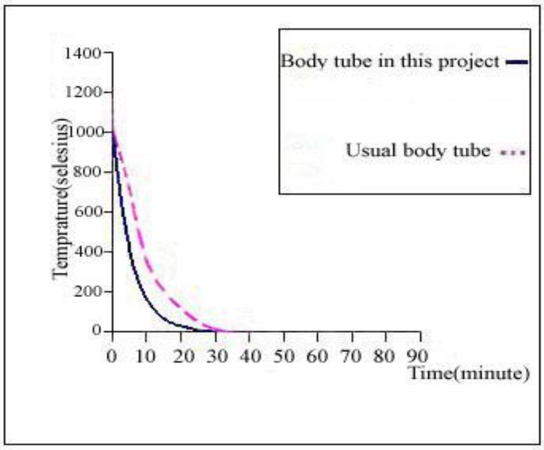

Figure 4. Heat reduction rate (speed of heat reduction) in usual Tube and in this study.

DISCUSSION

Practical researches in the research center of Siemens Company resulted maximum of 40% increase in cooling rate. Nonetheless, the best finding was the metal septum lamp of Philips Company whose cooling rate increased about 500 percent [7-8]. The cooling rate of our produced lamp is about 1000 percent. These achievements reside in the geometric form or the increase in the effective area and the substance of alloy which relatively has a higher conductivity coefficient than the framework of ordinary lamps [10]. This process causes less restoring of heat in this lamp during its operation and enhances its cooling rate. Hence, this kind of lamp is more durable and can be utilized for X-ray generating with high intensities in extremely long or short terms of time. These two items are accordingly very significant in new radiotherapy methods and modern cancer diagnosing and angiography. High intensities of X-rays are also critically important in industrial radiography. These lamps are the only facilities to obtain this level of intensities and have very effective efficiency in new photo electrotherapy methods[14-16].

Increasing the conditions of radiation especially to this level, needs increasing the cooling rate of the lamp or applying some methods to reduce the heat accumulation in it.
This study has been executed, especially to ease the conditions of increasing the intensity of radiation required for photo electrotherapy.
These Stratton pipes are equipped by the oil convectional cooling system. Since, because of the direct contact of molecules, the transition of heat due to convection is more than radiation, the cooling rate increases[17].
Additionally, an internal rotating system as a layered mixer creates a whirlpool shape flowing

of oil around the lamp, and in this vein, the rapid oil current goes around the lamp and from the other side, is transmitted to a radiator, which is cooled by a fan. This flowing, totally enhances the cooling rate 40% more than ordinary cooling system operating with oil current. Philips Company offered a new X-ray generator lamp with a metal framework. The design of this generator resembles the former generators and only the substance of the framework is changed and is made of metal instead of glass. In these lamps, electrodes of anode and cathode are installed on ceramic plates which are suitable electrical and heat insulators[18-19].

These ceramics prevent the contact of the framework and electrodes. The ball bearings are separated inside the ceramics. In these lamps, the pivots of rotating anode are installed from both sides' on the ball bearings; thus, the mass of the anode is increased by 80%. Increasing the mass and consequently, the anode surface scatters the heat faster by radiation and increases its heat resistance against melting or softening. The metal framework, due to a higher heat coefficient than glass, boosts the cooling rate and consequently the heat resistance of the lamp. Besides, it prevents the mercurating of the lamp which is the result of the tungsten vapor on the internal surface of the lamp. Therefore the framework is basically electrical self-conductor and the tiny layer of tungsten vapor cannot change its conductivity. Nevertheless, in this design, the shape of lamp is not changed ;thus, the cooling rate is relatively increased just by raising the conductivity coefficient (5 times increasing). Moreover, in this design, the framework is in a shape that the oil which is surrounds it is not eliminated and this factor is the most serious defect of the product[22-23].

The cancer research center of London, applied the water flow with high rotating speed, for therapeutic X-ray lamps which requires a high level of heat resistance for generating high quantities of ray in high voltage conditions (300 kvp and 1 minute periods of time). This system increases the heat resistance of lamps from 900 w (for ordinary water cooling systems) to 1250 w[26].

CONCLUSION

This design, in addition to presenting a practical and scientific path and the essential experience for producing a framework with a new design and high heat resistance, has a very significant practical goal. The foremost objective of this design is approaching the possibility of producing X-ray for therapeutic with photo electrotherapy system. This system is a new method for cancerous piled tumors therapy. In this method, the high intensity of X-ray (between 150 to 200 mil-amperes) and the energy of 200 to 300 kilo volt pick are required. The only – so far – producer of therapeutic X-ray lamps (Gulmay Company) offered the last series of its X-ray lamps with utmost 300 kilo volt pick, 10 mil-ampere and 2 minutes of time. In this new lamp, with reducing the kilo volt pick to 200 kilovolt, 15 mil-amperes can be chosen, while for photo electrotherapy in 300 kilo volt pick, the intensity between 150 to 200 mil-amperes is more appropriate[15].

The proposed design is primarily concentrated with the factors of cooling rate or heat accumulation in X-ray generator lamps to provide the accessibility of higher intensities of radiation for the mentioned functions, especially higher intensity in high kilo voltage, which are significant in new radiotherapy. In this project, the engineering design. A new shape for increasing the effective area of the framework and some modifications in the substance of the framework, which are the essential items for raising the cooling rate, are recommended [20-23].

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