TOTAL BODY IRRADIATION WITH AN ALUMINUM COMPENSATOR FABRICATED USING WATERJET TECHNOLOGY

An Undergraduate Research Scholars Thesis

by

MADISON NAESSIG and SOLEIL HERNANDEZ

Submitted to the Undergraduate Research Scholars program at
Texas A&M University
in partial fulfillment of the requirements for the designation as an

UNDERGRADUATE RESEARCH SCHOLAR

Approved by Research Advisor: Dr. John Ford

May 2018

Major: Radiological Health Engineering

TABLE OF CONTENTS

ABSTRACT

Total Body Irradiation with an Aluminum Compensator Fabricated Using Waterjet Technology

Madison Naessig and Soleil Hernandez
Department of Nuclear Engineering
Texas A&M University

Research Advisor: Dr. John Ford
Department of Nuclear Engineering
Texas A&M University

We propose the utilization of waterjet-fabricated aluminum compensators in total body irradiation (TBI) treatments using the technique known as AP/PA. Lead was substituted with aluminum to create a safer and more efficient compensator design, which was then constructed using SOLIDWORKS. The Engineering Innovation Center at Texas A&M University used a ShopBot Auto Router to fabricate the final prototype. In future directions, the prototype's performance will be analyzed by measuring surface dose information using an anthropomorphic phantom. From this information the uniformity of dose distribution will be assessed and compared to that of current lead compensators to determine the efficiency of the proposed substitution.

ACKNOWLEDGEMENTS

We would like to thank our faculty advisor, Dr. John Ford, and our staff advisor at UT Health San Antonio, Dr. Neil Kirby, for their guidance and support throughout the course of this research. Thanks also goes to the fabrication technicians at the Texas A&M Engineering Innovation Center, as well as the department of Nuclear Engineering for financially supporting our fabrication efforts.

NOMENCLATURE

TBI	Total Body Irradiation
AP	Anterior to Posterior
PA	Posterior to Anterior
MCNP	Monte Carlo N-Particle Transport Code

CHAPTER I

INTRODUCTION

Cancer is one of the leading causes of death in America causing a need for technological advancement of treatment options in the medical field. In 2016 alone, more than 1.5 million new cases of cancer were diagnosed in the United States and more than half of those cases resulted in death. The most common and aggressive types of cancer are breast cancer, lung cancer, prostate cancer, and leukemia (National Cancer Institute). Currently physicians can treat a number of disease sites through the use of chemotherapy, surgery, and radiation therapy.

Radiotherapy

Radiation therapy uses ionizing radiation to kill cancerous cells in various disease sites of the body. The ionizing radiation can be delivered either internally or externally. Internal methods include brachytherapy, which implants radioactive isotopes directly into the malignant tumor. External radiation is a popular treatment option that uses technology such as a linear accelerator to deliver beams of ionizing radiation to a cancerous target.

Once the radiation has reached the appropriate target, it unwinds the DNA of the cancerous cells to slow further reproduction of unhealthy tissue. Ionizing radiation can be used as an exclusive method or it may be paired with other treatment options to enhance their effectiveness. A physician may use radiation therapy to reduce the size of a tumor giving a patient the option of surgery to extract the mass. Radiation may also be used in the palliative sense to improve a patient's quality of life while enduring the disease. As technology advances, physicians continue to manipulate radiation in order to give each patient's body the opportunity to confront and defeat cancerous tissue.

Total Body Irradiation

Total Body Irradiation (TBI) is a popular form of external radiotherapy used to prepare a patient for a bone marrow transplant, which is done by destroying a patient's bone marrow and tumor cells to compromise one's immune system and decrease the rejection of donor bone marrow. Low energy megavoltage photon beams deplete the bone marrow. TBI has the ability to treat leukemia, aplastic anemia, lymphoma, multiple myeloma, and autoimmune diseases.

There are various forms of TBI, however, current research focuses on the anterior to posterior method. This method requires a patient to be standing upright and slightly seated on a stand, similar to a bicycle seat, which is displayed in Figure 1. The patient is also surrounded by a cage-like structure in order for the patient to remain as still as possible throughout the duration

Figure 1. Patient orientation during TBI ("The B Word").

of the treatment. This orientation ensures a homogenous dose across the patient's body axis. The patient's body is not parallel to the linear accelerator causing the need for a shield to manipulate the beams for accurate dose delivery.

Compensators

A compensator is a particular type of shielding that is used to create a homogenous dose of radiation to a patient's orientation. Each patient requires a personalized compensator that relates patient measurements to dose distribution. Current compensators in radiotherapy are designed by medical physicists and manufactured out of thin, lead pieces. Because no two compensators are alike, the assembly process of a compensator requires extensive accuracy and time.

To construct a compensator, a patient's anatomy is separated into various regions of interest on a plate of plexiglass. Each region of interest such as the head, neck, shoulder, abdomen, hip, thigh, knee, and ankle, requires a different amount of lead to ensure a uniform dose across the patient's body axis. For example, since a patient is slightly seated, a region of interest such as the knee would require more compensation than say the ankle due to the fact that the knee is slightly closer to the source of radiation. The neck also requires more compensation due to the large amount of organs within that region.

Once the lead pieces have been oriented for each region of interest, they are attached to the plexiglass to form a full compensator as seen in Figure 2. The compensator is then attached to the gantry, which is the head of a linear accelerator, to be used in treatment. Radiation originates from the gantry and as it travels through the lead compensator, the material properties of lead allow it to absorb radiation that is not intended for a specific region of interest. This repeated process guarantees a uniform radiation dose to the patient.

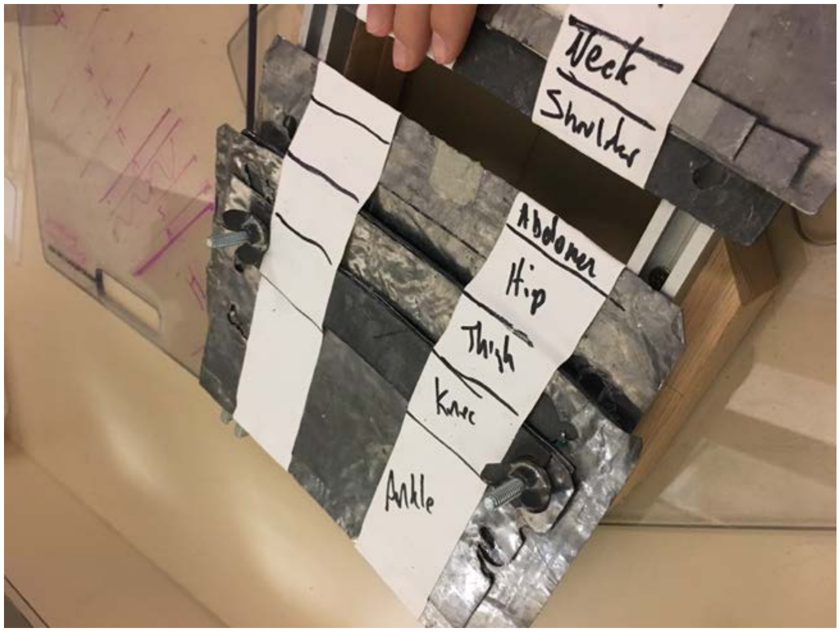


Figure 2. Assembled lead compensator.

CHAPTER II

MATERIALS AND METHODS

In the field of radiation protection, lead is a material that is commonly used to shield multiple forms of radiation including gamma rays. Lead effectively attenuates, the gradual loss of intensity through a medium, various forms of radiation due to its high molecular density. This particular element also has a high atomic number meaning it contains a numerous amount of electrons, which are able to absorb some of the radiation and cause it to scatter. If no shielding were present, lead or any other material, the electrons within a person could be affected causing their DNA to be damaged. However, it is important to not only consider the positive effects of lead, but the negative effects as well.

Design Challenge

Various problems have been observed with the current compensator design such as the material that is being used, safety concerns, and assembly time. Due to lead being a naturally dense material, it creates a heavy compensator to design and construct. Additionally, lead is not safe to work with over long periods of time, which complicates a physicist's ability to work on a design for multiple hours. If a physicist is exposed to too much lead over a long period of time they could experience various health concerns such as lead poisoning, high blood pressure, and kidney damage. Changing the compensator design and material will maximize the efficiency of TBI by eliminating the current treatment concerns.

The material will be changed from lead to aluminum in order to create a safer environment for the medical physicists and their patients. Previous research has shown that using Nylon as the compensator material did not create a homogenous dose across the body axis, therefore Aluminum was chosen for current research. Aluminum was chosen as the new material because it doesn't affect the health of a person when exposed to it for long periods of time, it's cheaper to fabricate, and not as heavy as the material used now. Aluminum also has a better attenuation than nylon giving a smaller variation in dose. In order to compensate for the high density of lead, medical physicists will have to use four times the amount of aluminum compared to lead.

Additionally, creating a design with fewer and more uniform pieces will allow a shorter assembly time and reduce manufacturing costs. It would be beneficial to have a small selection of pieces that are able to accommodate all measurements of compensator thickness that are generated from human body measurements. Implementing an interlocking method vertically and horizontally could also potentially lead to a shorter assembly time. This part of the design will also create a more stable and efficient compensator, which is another one of the overall challenges and goals of this research.

Design Process

Multiple design options were considered before the final design was fabricated. Each design was constructed using SOLIDWORKS 3D Design software. The first design was based on the idea of Lego pieces. Multiple pieces would be fabricated to snap together so that they could be stacked to match each thickness associated with each ROI. The problem with this design was that the properties of aluminum and plastic are drastically different. The thickness of aluminum needed for appropriate attenuation was much thicker than that of the plastic used in Lego pieces and because of this, the design was ultimately considered not optimal.

The next design consisted of three rectangular pieces of aluminum of 1 cm, 2 cm, and 4 cm thickness. By using these multiplies of piece widths, virtually any thickness could be constructed from some combination of these three pieces. Each piece had extruded oval cut openings on the left and right side of the rectangle so that each piece could be bolted down onto plexiglass. The oval design allowed for each piece to slide up and down the plexiglass base so that there could be more manipulation in the design for the physicist. The design was constructed on SOLIDWORKS but was decided against due to stability purposes.

The final design combined the most beneficial aspects of each previous prototype. As shown in Figure 3, the widths of the rectangular pieces were kept at 1 cm, 2 cm, and 4 cm. Each rectangular piece had a circular extruded cut on the left and right hand side. The amount of extrusions on each piece corresponded to the width of the piece. For stability purposes, an interlocking method was designed and implemented. Each aluminum part has extrusions on the top of bottom of the piece, which allows each part to slide and lock together to make for a uniform and stable design.

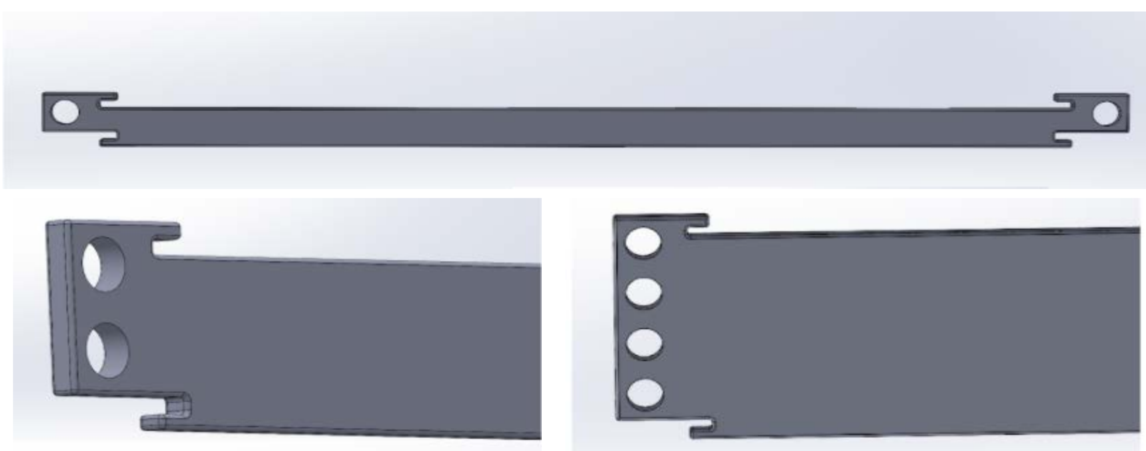


Figure 3. SOLIDWORKS 3D Design of a 1cm, 2 cm, and 4 cm aluminum rectangular piece.

To further ensure stability, two threaded rods were constructed to be 14 inches long with 35 threaded ¼-20 holes. The piece displayed in Figure 4, will slide onto an apparatus similar to that in Figure 2 to attach the layers of aluminum rectangular parts to a sheet of plexiglass that can then be attached to the head of the linear accelerator.

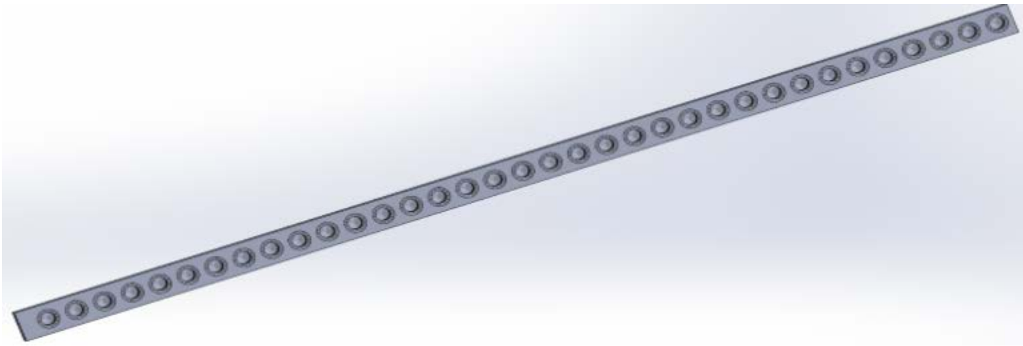


Figure 4. 14 inch aluminum rod consisting of 35 holes threaded for 1/4 -20 screws.

Once each part was assembled in SOLIDWORKS 3D Design, the assembly feature of the program was used to ensure the locking mechanism would work as intended. This feature allows each piece to be uploaded into the assembly window and manipulated into a final assembly to confirm measurements of each piece. The two threaded rods were put in place as a frame and the rectangular pieces were interlocked and stacked together. An assembly of the final design can be seen in Figure 5.

Figure 5. Assembly of final compensator design.

3D Printed Prototype

To further ensure the accuracy of measurements and the aesthetic of the final design, a 3D print of the prototype was fabricated at the Engineering Innovation Center at Texas A&M. To do this, the Solidworks design of each piece was converted into an stereolithography file (STL) and sent to the Engineering Innovation Center 3D printing technicians. The 3D printer selected was a Stratasys EDEN 260V, which has a corresponding build volume of 255 x 252 x 200mm. The printer also has a 16-micron layer accuracy and 7-micron dimensional accuracy which led for correct measurements to ensure the interlocking method was feasible. The material chosen was Objet VeroWhite which is an opaque printing material that is water resistant. Although no water was being used in this experiment, this was a feature found unique to a compensator design.

Figure 6. 3D printed pieces for first prototype.

The printed products can be observed in Figure 6. A 2cm, 4cm, and 1cm was printed along with an extra 1cm piece and 4 thread rods. The original two thread rods in the STL were cut in half due to the volume limitations on the 3D printer. To bring the Solidworks assembly to life, a package of ¼-20 screws was purchased and used to connect the individual compensator pieces to the thread rods. Because the rods were half the intended size, two rods were screwed together to produce two full size 14 in thread rods. To accomplish this, a hole was drilled on each rod to make room for a screw to go through the printed material. Due to cost limitations, only 5 compensator pieces were printed for the prototype. It should be noted that in a real compensator, multiple pieces would be printed so that each region of interest could be represented by the correct number of pieces. In order for this compensator to be tested and used in the clinic, more pieces would be printed to assemble a full compensator that can meet the needs of a patient. The final compensator prototype from the 3D printer can be seen in Figure 7.

Figure 7. The first fully assembled 3D printed prototype.

CHAPTER III

RESULTS AND DISCUSSION

Following the 3D printed prototype, an aluminum prototype was manufactured. The Engineering Innovation Center was consulted again to create a prototype from a Solidworks file using a ShopBot Auto Router. EIC Fabrication Shop manager, Todd Williams, used the Standard ShopBot model to bring the design to life and the specifications of the chosen machine are detailed in Appendix B. ShopBot Auto Routers are an efficient CNC fabrication option due to their high speed and accuracy. The machine is able to interpret a file from an AutoCAD software such as Solidworks and configure a prototype from it. To do this, the machine acts as a robot and precisely cuts each part according to the design specifications set on the computer. The machine uses computer driven tools to cut away material and build up material to achieve a final prototype with high precision.

Final Design

The final aluminum design resembled the 3D printed design closely. The measurements on the interlocking pieces on the top of bottom of each compensator part were adjusted to be more accurate. Figure 8 demonstrates two compensator pieces attached together. It became evident that the rigid metal pieces did not attach as securely as the 3D printed model due to the difference in the material properties of plastic and aluminum. To improve this, a more secure interlocking design may be considered in the future.

Figure 8. Interlocking method on aluminum fabrication.

Additionally, Figure 9 displays the stacking method that was implemented to allow the compensator to be "built-up" to correlate with the associated region of interest thickness for each patient based on patient measurements. The stacking method performed as expected and proved to be a secure design aspect of the compensator design. When the compensator is used in the clinic for testing, the stacked pieces would be secured to the thread rod using a ¼-20 screw on each side of the compensator.

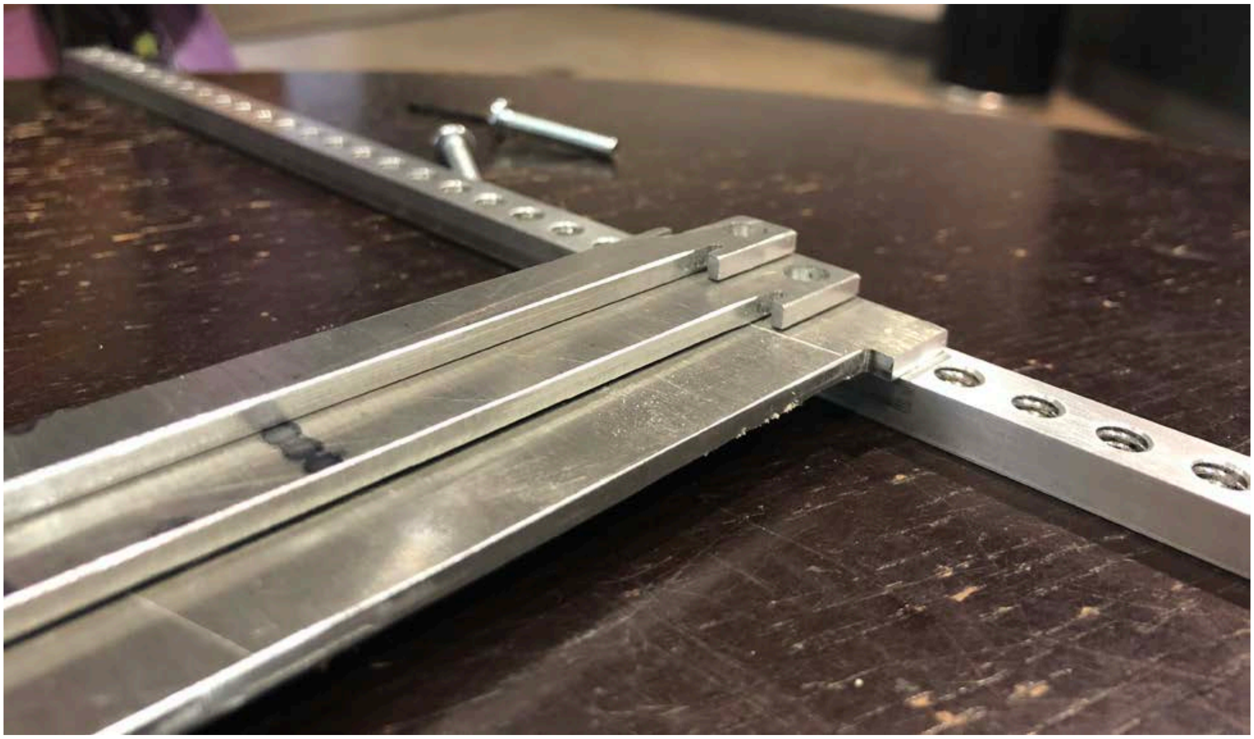


Figure 9. Stacking method for aluminum prototype.

To demonstrate the security and stability of the design, 1/4 -20 screws were detached from the 3D printed prototype and were called upon to assemble the aluminum prototype. Figure 10 presents the ¼-20 screw acting as an anchor in the final aluminum prototype. The screws were a unique aspect of the design because it allows each piece to be connected in more ways than previous designs. A physicist will be able to slide pieces up and down a layer to guarantee a precise piece for each region of interest. As long as the holes of each piece are lined up accordingly, they can be safely secured to the thread rods which are then secured with bolts to a piece of Plexiglas to be attached onto the head of the linear accelerator.

Figure 10. ¼-20 screw anchoring a 2cm and 1 cm compensator piece

A final assembly of the proposed aluminum compensator can be observed in Figure 11. It should be stated that the compensator used in a clinic would have multiple 1 cm, 2 cm, and 4 cm pieces assembled in a variety of ways to match a patient's unique anatomy. Before this compensator would be tested and implemented into the clinic, a more elaborate design would be fabricated using a CNC waterjet as opposed to a ShopBot. Overall, the aluminum proved to be a viable compensator material option, but design adjustments are still necessary to prevent ionizing radiation from leaking through certain aspects of the final prototype. This possible leakage could also be confirmed or denied in the future by testing the aluminum compensator in various mock treatments and analyzing the data gathered from those treatments.

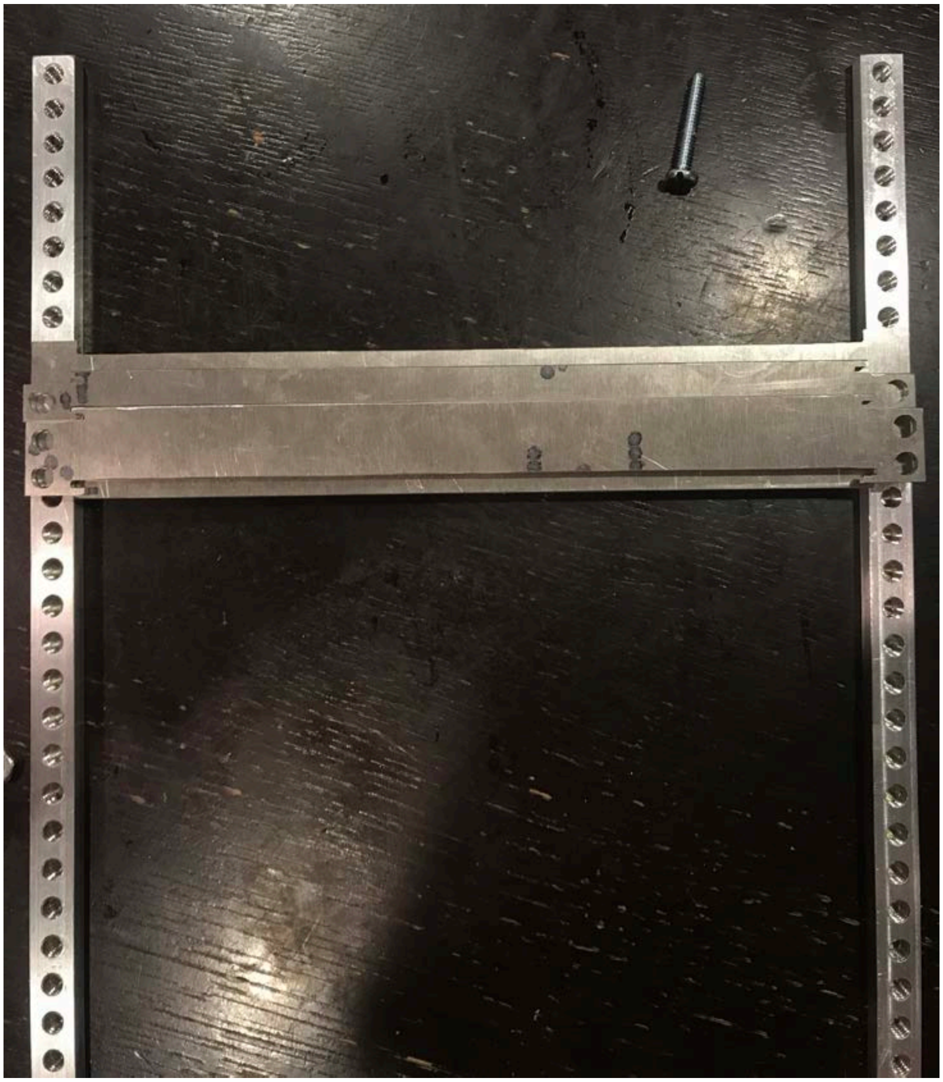


Figure 11. Final Aluminum Prototype

CHAPTER IV

CONCLUSION

After completing the design and fabrication, it is imperative to test the aluminum compensator in order to ensure that it gives a homogenous dose with a small variation, which will then allow the design to be implemented into the clinic. Multiple mock treatments need to be completed to collect sets of data that will be analyzed to establish how well the aluminum compensator design works and if any improvements need to be made to accomplish maximum efficiency. The goal of this project was to provide medical physicists a simpler, easier, and healthier way to construct compensators for each individual patient, which has been accomplished and the future directions for this project will guarantee it.

Future Directions

The first part of testing the design that was created during this project is to use an anthropomorphic phantom. There are many different models of phantoms, however the one that is going to be highly considered for this design is the Whole Body Phantom Kyoto Kagaku PBU-50. A company known as Supertech X-Ray manufactures this particular model and the company describes their model as “state-of-the-art synthetic skeleton, lungs, liver, mediastinum and kidneys embedded in Kyoto Kagaku original soft tissue substitute” (Supertech). The purpose of a phantom is to mimic how a human body will react to certain radiotherapy treatments such as TBI. It allows unlimited repetitions of treatment, unlike a human, to gather higher amounts of data, and the anthropomorphic phantom is more closely related to a live human skeleton due to the fact that cadaveric human skeletons can often shrink in size over time.

Figure 12. Whole Body Phantom Kyogo Kagaku PBU-50

The anthropomorphic phantom as seen in Figure 12 will be positioned similarly to the AP/PA technique as seen in Figure 1, since that is the technique the aluminum compensator was based off of. The aluminum compensator will be attached to the gantry head of the linear accelerator, and multiple mock treatments will be conducted in order to gather data for this design. This part of the future directions for this project will most likely be done at the UT Health Cancer Center in San Antonio under the supervision of the medical physicists currently at the center.

Many computer code programs are used in the field of radiological sciences, however the program that will be used to evaluate and analyze the data obtained from mock treatments is known as Monte Carlo N-Particle Transport Code (MCNP). This particular code models the transport of neutrons, electrons, and photons, and provides calculated values based off of the model the code generates. The MCNP code "treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first-and second-degree surfaces and fourth-degree elliptical tori" (Los Alamos National Laboratory). The information that is obtained from MCNP will reveal how efficient the aluminum compensator design is and whether or not it is feasible to use during TBI treatments.

Another important future direction that has been discussed is the use of a Waterjet machine to create the individual pieces of the compensator if this design is implemented in various cancer centers. The Waterjet machine uses a high-pressure water stream to cut narrow lines in all types of material including aluminum. The use of a Waterjet also limits human error because it follows the design created on a file that is imported to the computer whereas other fabrication machines are done manually, which can lead to minor details straying from the original design. This machine is efficient and versatile, and in order for numerous parts that have an elaborate design to be manufactured quickly then the use of the Waterjet is the best choice.

REFERENCES

"Cancer Statistics." *National Cancer Institute*, www.cancer.gov/about-cancer/understanding/statistics.

The B Word | May, www.bobmorgan.org/bword/2010/05/.

Su, L, et al. "Chemical Design of Both a Glutathione-Sensitive Dimeric Drug Guest and a Glucose-Derived Nanocarrier Host to Achieve Enhanced Osteosarcoma Lung Metastatic Anticancer Selectivity." Journal of the American Chemical Society., U.S. National Library of Medicine, 31 Jan. 2018, www.ncbi.nlm.nih.gov/pubmed/29350522.

"Whole Body Phantom Kyoto Kagaku PBU-50Use for X-Ray Training, Disarticulates into 10 Phantoms." *Whole Body Phantom PBU-50, Full Body for X-Ray, Radiography Training Kyoto Kagaku, Positioning Manikin*, Supertech, www.supertechx-ray.com/Anthropomorphic/FullBodyPhantoms/PBU-50.php.

"A General Monte Carlo N-Particle (MCNP) Transport Code." *Los Alamos National Laboratory: MCNP Home Page*, Los Alamos National Laboratory, 2009, mcnp.lanl.gov/.

"The Full Size PRSalpha CNC." PRSalpha CNC Routers, www.shopbottools.com/mProducts/prSalpha.htm.

Dyk, Van J., et al. "The Physical Aspects of Total and Half Body Photon Irradiation." *American Association of Physicists in Medicine*, vol. 17, June 1986, pp. 1–60.

Ulrich Quast, Total body irradiation—review of treatment techniques in Europe, Radiotherapy and Oncology, Volume 9, Issue 2, 1987, Pages 91-106, ISSN 0167-8140, http://dx.doi.org/10.1016/S0167-8140(87)80197-4.

Galvin, J.M.: Calculation and prescription of dose for total body irradiation. Int. J. Rad. Onc. Biol. Phys. 9:1919-24, 1983.

Quast, Ulrich. "Whole Body Radiotherapy: A TBI-Guideline." *Journal of Medical Physics / Association of Medical Physicists of India* 31.1 (2006): 5–12. *PMC*. Web. 29 Aug. 2017.

Khan, F.M., Williamson, J.F., Sewchand, W., Kim, T.H. Basic data for dosage calculation and compensation. Int. J. Radiat. Oncol. Biol Phys. 6: 745-751, 1980

APPENDIX A

Total Body Irradiation Aluminum Compensators

Soleil Hernandez | Madison Naessig

UNDERGRADUATE RESEARCH SCHOLAR

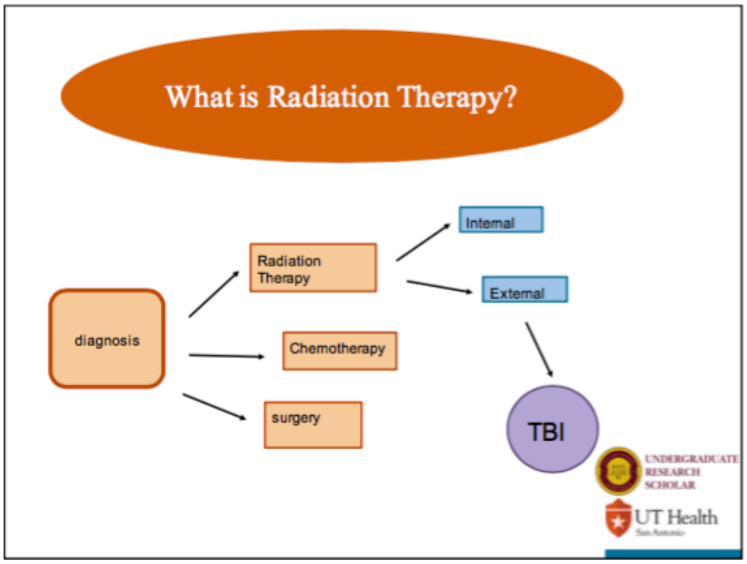
UT Health San Antonio

Overview:

- What is Radiotherapy/ TBI
- What is a Lead Compensator?
- Our Project
- Future Directions
- Questions

UNDERGRADUATE RESEARCH SCHOLAR

UT Health San Antonio



What is Total Body Irradiation?

UNDERGRADUATE RESEARCH SCHOLAR
UT Health

Total Body Irradiation (TBI)

Purpose of TBI?

- Form of radiotherapy used to prepare a patient for bone marrow transplant
- Destroys the patient's bone marrow and tumor cells
- Compromises the immune system

UNDERGRADUATE RESEARCH SCHOLAR

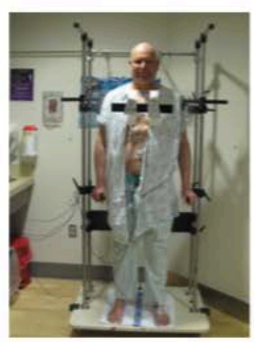
UT Health San Antonio

Total Body Irradiation (TBI)

What is TBI?

- Low energy megavoltage photon beams delivered
- AP/PA
  - Standing upright
  - Seated on a stand
  - Compensator

http://www.bobmorgan.org/bword/2010/05/



UNDERGRADUATE RESEARCH SCHOLAR

UT Health San Antonio

What is a Lead Compensator?

UNDERGRADUATE RESEARCH SCHOLAR
UT Health San Antonio

Lead Compensators

- Ensure a homogenous dose along the body axis (+/- 10%)
- Compensator base
  - Diagonal orientation
  - Sectioned by ROI
- Compensator thickness dependent on:
  - Beam energy
  - Material
  - Distance

UNDERGRADUATE RESEARCH SCHOLAR
UT Health San Antonio

Lead Compensators

Calculation for | V3 | AP

Name 0 | CTRC # 0

* Measure each filter length from the tray for AP and PA filter length *

Section	AP Filter Thickness (mm)	Comments	
Head	0.8	0.4 +0.4 = 0.8	
Neck	2.7	0.4 +0.4 +0.8 +0.8 +0.4 = 2.8	
Shoulder	1.7	0.4 +0.4 +0.8 = 1.6	
Chest	0.6	0.4	
Umbilicus	0.6	0.4	
Hip	0.0	0	
Thigh	2.5	2.4	
Knee	4.2	2.4 +1.6 = 4	
Ankle	2.2	2.4	

Total Thickness of lung block (cm)	In Lead	In Cerrobend
	#N/A	#DIV/0!

- Sectioned off by ROI
- Find AP Filter Thickness
- Assemble lead pieces

UNDERGRADUATE RESEARCH SCHOLAR

UT Health San Antonio

Lead Compensators

What's the problem?

- Weight
- Time
- Health concerns

UNDERGRADUATE RESEARCH SCHOLAR

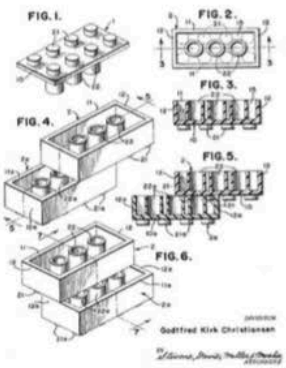
UT Health San Antonio

Our Project

Task

- Change material to aluminum
- Shorten assembly time
- Simplify compensator design

Thought Process

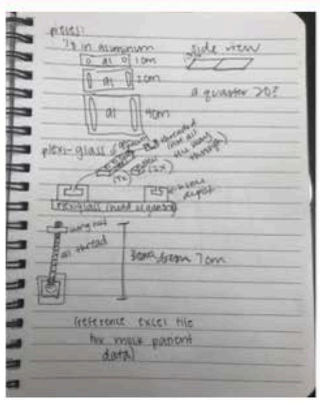


- Interlock pieces similar to Lego design
- Concerns about thickness of aluminum
- Aluminum properties differ from plastic

UNDERGRADUATE RESEARCH SCHOLAR

UT Health

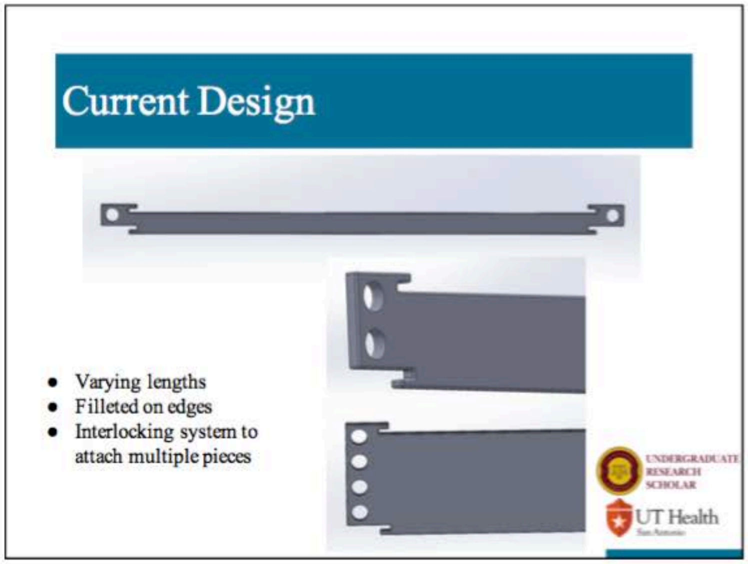
Thought Process

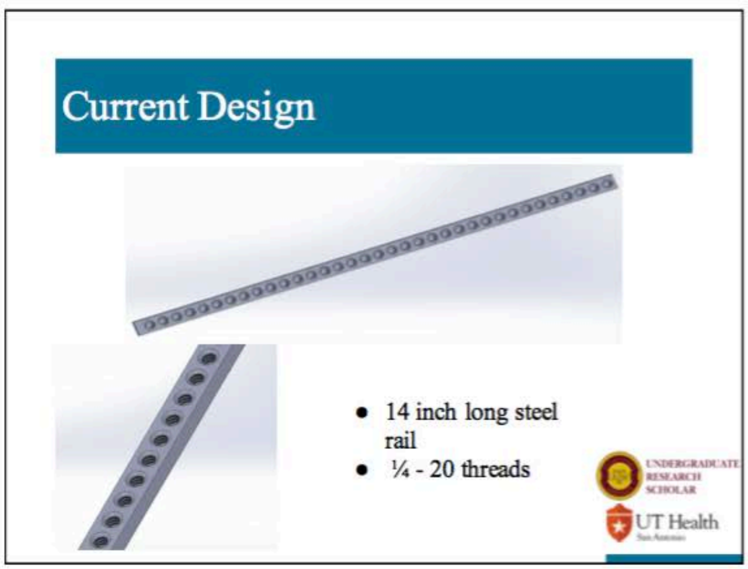


- Uniform thickness and width with varying lengths
- Extruded oval openings
- Steel rail with ¼ - 20 threads
- 7 cm threaded rod
- Wing nuts

UNDERGRADUATE RESEARCH SCHOLAR

UT Health


Current Design
Varying lengths
Filleted on edges
Interlocking system to attach multiple pieces
UNDERGRADUATE RESEARCH SCHOLAR
UT Health


Current Design
14 inch long steel rail
¼ - 20 threads
UNDERGRADUATE RESEARCH SCHOLAR
UT Health


Current Design
UNDERGRADUATE
RESEARCH
SCHOLAR
UT Health

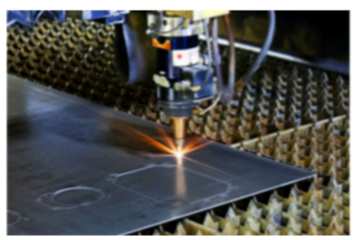

Current Design
UNDERGRADUATE
RESEARCH
SCHOLAR
UT Health

Future Directions

Fabrication

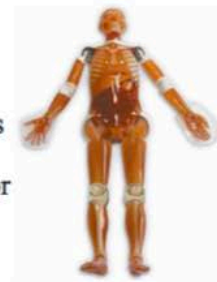
Engineering Innovation Center

- Drawings have been constructed of each piece
- Designs submitted to EIC
- Currently fabricating it and next phase is to test it



Anthropomorphic Phantom

- Life size phantom with synthetic skeleton, lungs, liver, and kidney
- Used to compare dose distributions along the body axis
- Allow researchers to gather data for their designs



UNDERGRADUATE RESEARCH SCHOLAR
UT Health San Antonio

Questions?

UNDERGRADUATE RESEARCH SCHOLAR
UT Health San Antonio


Thank you!
UT Health

APPENDIX B

ShopBot®

Full Size Gantry Tools

If you're looking for a CNC solution that delivers affordable, full-production performance in the digital fabrication of wood, plastic, aluminum, and other materials, then ShopBot's full sized gantry tools are the right option for your needs. Using advanced technology for CNC cutting, drilling, carving, and machining, ShopBot's full size gantry tools are easy to configure and re-configure, easy to learn and use.

Available in traditional shop-size and larger, all full size gantry tools are available with 8" or 14" Z travel. In addition to our standard size tools – 96 x 48, 96 x 60, 120 x 60, 144 x 60 – we can build your tool to any dimension up to 10' by 30' and with plunge depths up to 24 inches. Other customizable components are available, including dual Z options with two Z axes on the main gantry.

Give us a call to discuss your production needs.
We'll help you choose the right tool to get the job done.

All Full Size Gantry Tools Include:

- Tough precision linear bearings on the moving gantry and hardened steel rails for the X-axis.
- Reliable rack-and-pinion power transmission on each axis.
- Positional repeatability of +/- .002".
- Sealed industrial control box.
- Z-zero touch-off plate and XYZ proximity switches.
- Dust skirt ready to connect to your dust collector.
- Advanced ShopBot developed and ShopBot supported Control System software runs your CNC.
- Bundled with two powerful design programs to create CNC projects.
- Fully-assembled gantry module ships along with steel and aluminum table components. The engineering of our structurally integrated table allows on-site assembly and the advantage of placement of the tool in work areas with limited accessibility—while still having a factory squared, aligned, and tested machining system.
  We also offer on-site set-up services, as well as training and production process consulting as options.
- Unparalleled support for our user community with forums, production support services, training classes, and FREE technical support.
- Two-year warranty.

PRSstandard Specifications

Our **PRSstandard series** of full-sized gantry tools provides an affordable entry to CNC for those who are ready to get started with CNC productivity. The tools are ideal for moderate production shops, educational settings, hobbyist garages, signmakers, woodworkers, artists, and DIYers (to name but a few). PRSstandard tools have the same rigid gantry, table frames, and durable mechanical components as our top-of-the-line PRSalpha series.

- Low-backlash gearhead stepper motors on all axes.
- Smooth RBK Series stepper drivers on all axes.
- Step resolution .0006".
- Positional repeatability of +/- .002".
- Emergency stop disconnect switch integrated in control box.

PRSalpha Specifications

With enough production capability for a three-shift factory, **ShopBot PRSalpha tools** are our toughest, most sophisticated, gantry-based CNC routers. They reach rapid transit speeds of 1800 inches per minute and cutting speeds of up to 720 inches per minute. The PRSalpha series of full sized gantry tools deliver high performance, high efficiency production, as well as fast position and cutting.

- Fast, closed-loop Vexta alphaStep motors fitted with low-backlash, tapered-hob gear heads on all three axes (two on the X-axis) — alphaStep system monitors motor shaft positions with feedback maintaining tight synchronicity between signal and motion.
- Step resolution of .0004".
- Emergency stop disconnect switch in the control box with integrated and cabled remote emergency stop buttons.

ShopBot®
888-680-4466 • ShopBotTools.com

We make the tools for making the future.

JUL2017

PRSstandard & PRSalpha Dimensions (Length x Width*** x Plunge**)

	48-48	96-48	96-60	120-60	144-60
Nominal Cutting Area	48" x 48" x 6" (1.22m x 1.22m x 0.15)	96" x 48" x 6" (2.44m x 1.22m x 0.15m	96" x 60" x 6" (2.44m x 1.52m x .15m)	120" x 60" x 6" (3.05m x 1.52m x .15m)	144" x 60" x 6" (3.66m x 1.52m x .15m)
Total Movement Area	50" x 50" x 8" (1.27m x 1.27m x .2m)	102" x 50" x 8" (2.49m x 1.27m x .2m)	102" x 62" x 8" (2.49m x 1.57m x .2m)	122" x 62" x 8" (3.10m x 1.57m x .2m)	146" x 62" x 8" (3.71m x 1.57m x .2m)
Footprint	L72" x W79"x H67" (1.83m x 2.01m x 1.70m)	L120" x W79" x H67" (3.05m x 2.01m x 1.70m)	L120" x W91" x H67" (3.05m x 2.31m x 1.70m)	L144" x W91" x H67" (3.66m x 2.31m x 1.70m)	L168" x W91" x H67" (4.27m x 2.31m x 1.70m)

** Plunge distance is approximate distance from collet to table (assuming 2" of table material). Note that a long cutting bit will reduce the height of material that can be cleared by the cutter.
***Width is decreased by 10" when using a second Z-axis.

ShopBot Standard vs. Alpha Tool Specification

	Standard	**Alpha**
Drive Motor	Open loop steppers with 3.6:1 gearboxes. Without positional feedback, if attempting to cut too fast or an obstruction hit, steps could be lost and not noticed until the part file has completed or the operator stops.	Closed loop steppers with 7.2:1 gearboxes. With constant positional feedback to the drivers, if an obstruction is hit or cutting too fast the drivers will attempt to correct the position of the motors before activating an alarm, stopping the machine and displaying an alarm on the monitor. Once reset and homed, cutting should be able to be resumed.
Cutting Speed: **Porter Cable Router (7518)** **4HP Spindle**	 Up to 600" per minute Up to 600" per minute	 Up to 600" per minute Up to 720" per minute
Jog Speed (Bit out of material)	12" (300mm) per second	30" (760mm) per second
XY Move Speed	Variable, max. 300" (7.62m) per minute	Variable, max. 720" (15.24m) per minute
Z Move Speed	Variable, max. 180" (4.57m) per minute	Variable, max 360" (9.14m) per minute
XY Positioning Speed	Variable, max. 500" (12.7m) per minute	Variable, max 1800" (45.7m) per minute
Z Positioning Speed	Variable, max. 240" (6.1m)	Variable, max. 900" (22.86m) per minute
Step Resolution (Distance per step)	.0006" (0.015mm)	.0004" (0.01mm)
Postional Repeatability	±0.002" (0.05mm)	±0.002" (0.05mm)
Linear Cutting Force	≈50# at 1" (25mm) per second	≈150# at 1" (25mm) per second
X- and Y-Axis Drive System	Rack and Pinion	Rack and Pinion
Z-Axis Drive System	Rack and Pinion	Rack and Pinion
Electrical Power Requirements	110V 15A for Controls 110V 20A for Router (Spindle amperage requirements vary on horsepower and voltage)	220V 20A for Controls & Router (Spindle amperage requirements vary on horsepower and voltage)
Certification	None at this time	UL

Mechanical parts such as table, gantry, Z-axis… are the same for both types of machines.