Forging Process Analysis / Optimization for A Handle Block

By

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Abstract

The goal of this project is to optimize the forging process and reduce the number of steps (dies) required to manufacture the final product. A part was provided by Queen City Forging Company based in Cincinnati, Ohio. The part is a Handle Block used as a control lever in a heavy duty hydraulic control subject to maximum abuse in an outdoor environment The current forging process requires approximately 5 steps in order to produce the finished product. Through analysis and forging simulation the number of steps in the process will be reduced. Various 3D modeling (Solid Edge, Mechanical Desktop) and forging simulation (SuperForge) software packages are being used in the optimization process. Different die configurations and billet shapes are also being experimented with in order to produce the best configuration. Various factors such as post-forging manufacturing and simplicity are considered throughout the optimization process.

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Background

Forging is a process by which plastic deformation of the work piece is carried out by compressive forces. Forging is one of the oldest metal working processes and is very versatile. Various sizes and shapes of parts can be fabricated by using a forging process. A forging operation can be performed at room temperature (cold working) or at elevated temperatures. There are many advantages to forging, which include a refined grain structure and improved strength, ductility, and toughness. An example of how forging can affect the grain structure is shown below in Figure 1.

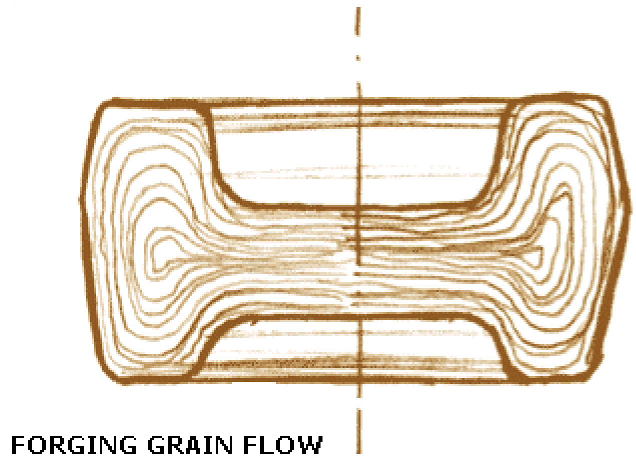

Figure 1: Forging grain structure

The three basic types of forging categories are open-die, impression die, and closed die (Kalpakjian, 295). Open-die forgings are made with repeated blows to the work piece with "open dies". An open die configuration allows the work piece material to overflow, which is called flash. In closed-die and impression die forging, the dies completely surround the work piece and very little flash if any occurs. A representation of an impression die forging process can be seen in Figure 2.

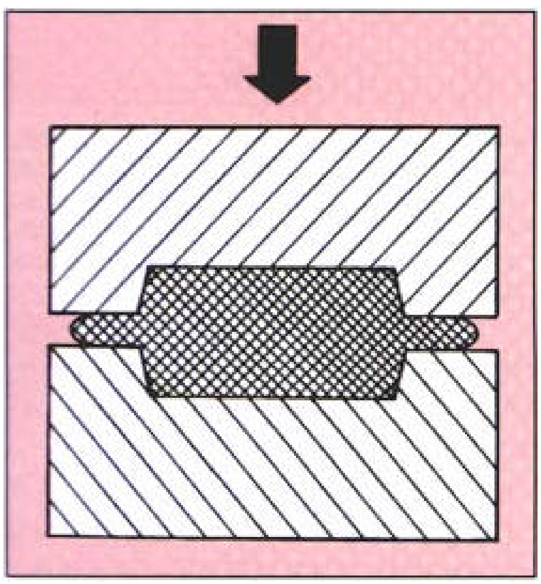

Figure 2: Impression Die Forging

CAD Modeling of the Dies and Billet

Two software packages were used in the process to create the final shapes of the components of the forging process. The 3D CAD modeling package Solid Edge is the primary tool used to represent the dies and billets in the forging process used by Queen City Forging Company. The other software package used in the creation of the dies is Mechanical Desktop. These packages are used because they are able to export files with the .stl extension, which is the file type needed for the analysis software, SuperForge. Mechanical Desktop was needed to make the dies because Solid Edge does not have a Boolean operation. It is much easier to draw the desired part in Mechanical Desktop and then perform a Boolean operation to create the upper and lower dies. These software packages were used because they provide a quick and easy tool to model the components of the process accurately. The first part that was drawn in Solid Edge was the desired finished shape of the part. This model is shown below in Figure 3 and was saved as a part file in Solid Edge (.par extension).

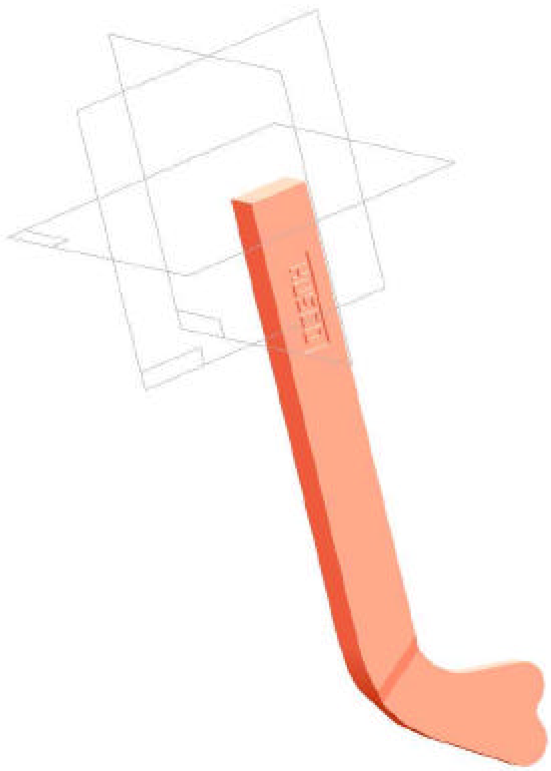

Figure 3: Desired finished part

Once the desired part was drawn, the first set of open-dies was created in Mechanical Desktop. The dies were created by first drawing the part as a 3D model and then performing a Boolean operation on a solid block of material. The die material was then cut in half to create the upper and lower dies. These die files were then imported into Solid Edge as a part file with the .par extension. The upper and lower dies are shown below in Figures 4 and 5, respectively.

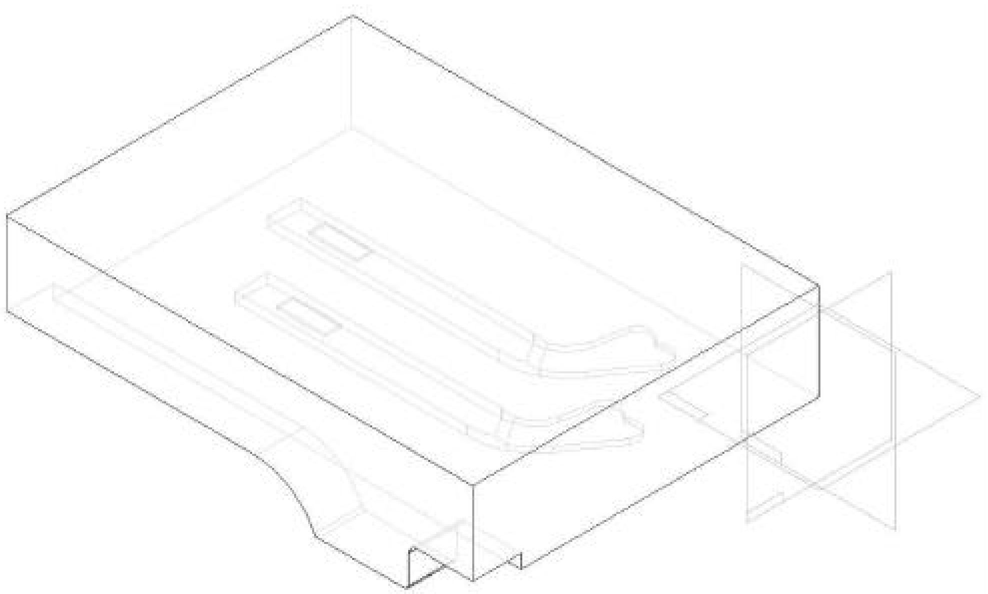

Figure 4: Top Die (Open)

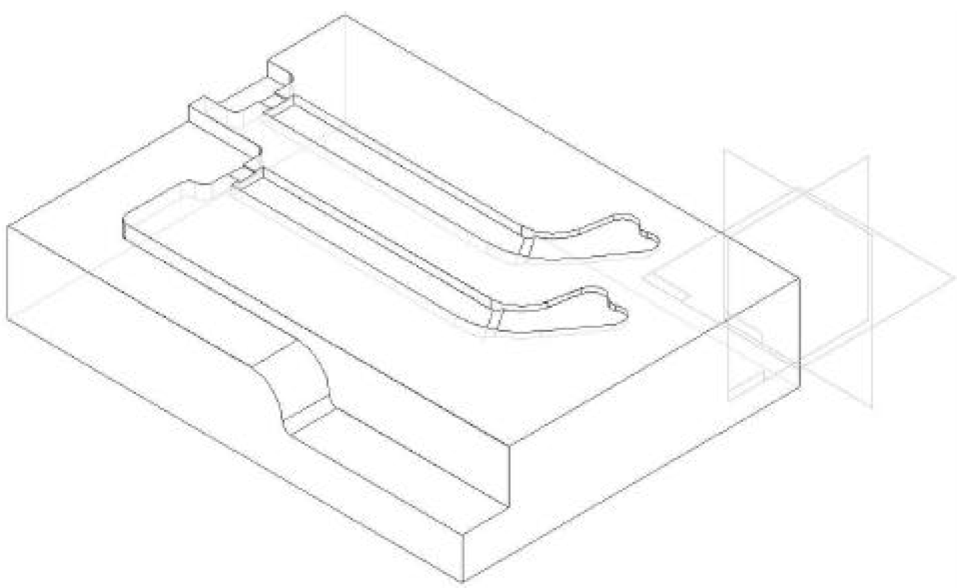

Figure 5: Bottom Die (Open)

There were problems when the dies were imported into Solid Edge from Mechanical Desktop. For some reason, the parts were imported very far away from the coordinate system. This created a problem in aligning the dies properly in SuperForge. To overcome the alignment problem a global coordinate system was first created.

Once the dies were modeld/created, a billet had to be created in order for the simulation process to be able to run in SuperForge. A very simple 0.625'' x 1'' x 12'' long billet was used for the first run of the process. For the first run, only the bending operation was tested and the billet is shown below in Figure 6.

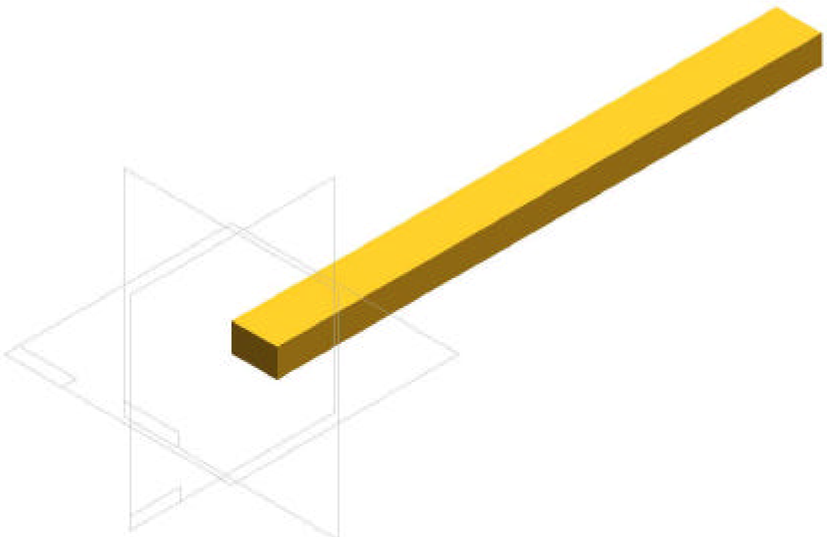

Figure 6: 1st run billet: 0.625'' x 1'' x 12'' long

After researching the processes used by Queen City Forging on their website, impression (closed) dies were created. The first set of closed dies used consists of a top die with a protrusion of the desired part and the bottom die with a cavity twice the thickness of the part. Drawings of these dies are shown in Appendix A.3 and A.4. The 3 billets tested with this set of closed dies are a straight billet and 2 bent billets. Drawings of these 3 billets appear in Appendix B.1, B.2, and B.3. Problems occurs in filling the die cavity properly so another set of closed dies were created.

The second set of closed dies consists of a bottom die that has a cavity equal to the thickness of the part and a top die with a small protrusion used to make a draft in the part. Both dies also have a section that will put the bend in the billet before it is forged. The drawings for the second set of closed dies appear in Appendix A.5 and A.6. Six bent billets were tested with this second set of closed dies and are shown in Appendix B.4 through B.9.

Analysis / Results

After the upper die, lower die, and billet were created in Solid Edge and Mechanical Desktop, the process is ready to run in SuperForge. Various process parameters such as die and billet temperatures and press speed were provided. The process was run with a hydraulic press with a very slow press speed (5 mm/sec) and the temperature was approximated as 600 Kelvin.

The first part of the process that was simulated in SuperForge was a bending operation of the rectangular billet with the open dies. This bending is needed if a rectangular billet is going to be used as the initial state of the work piece.

SuperForge produced a great deal of results from the simulation. The bending operation seemed to work very well with the dies, billet, and parameters that were used. An example of the results obtained from the SuperForge analysis is the plastic strain of the billet and is shown below in Figure 7.

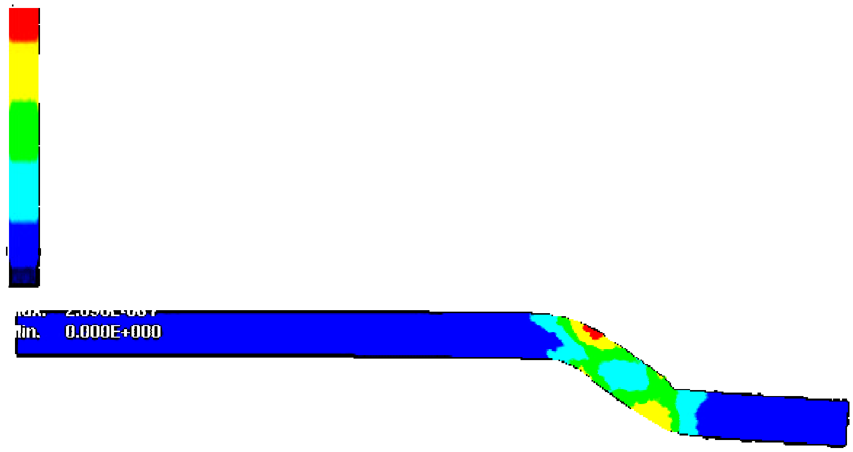

Figure 7: SuperForge results – Billet plastic strain for bending

After the bending operation was tested in SuperForge, the simulation was performed to test the forging section of the dies. The simulations with the first set of closed dies produced results that were not acceptable. The billets would either leave too much flash or would not fill the dies properly. The results obtained with the second set of closed dies were much better. The best combination of dies and billet was the second set of closed dies (Top Die v2 closed and Bottom Die v2 closed) and the bent billet 5-18-01 test billet 1. Figure 8 shows the plastic strain of the billet from the forging simulation performed in SuperForge.

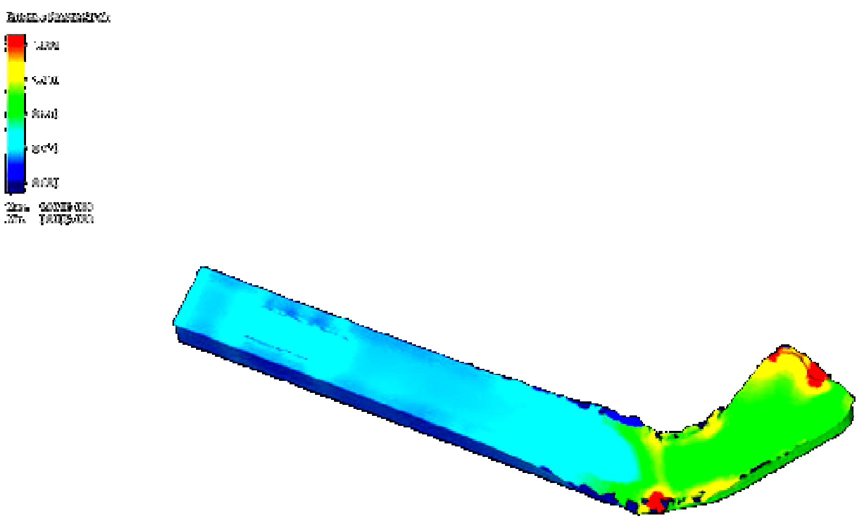

Figure 8: SuperForge results – Billet plastic strain for forging

It can be seen from Figure 8 that there is very little flash that occurs as a result of the forging process. Also, the die cavity was properly filled so the final dimensions of the part should be acceptable. The simulation of this forging was done in merely two steps: a bending and a blocker. Do to the favorable results mentioned, it is assumed that the forging process can realistically be shortened to just three steps: a bending and blocker stage, as mentioned, and a finishing stage as an added margin of safety.

Some problems occurred during the simulations using the second set of closed dies. One computer used had a newer version of SuperForge that had a smaller default value for the element size. This allowed the simulation to run much faster but the billets (5-18-01 test billets 2 through 5) were not filling the die cavity properly. The billets were actually losing volume because the element size was too large and did not accurately represent the shape.

Currently, all die designs are being redone to include certain essentials to the forging operation, such as relief angles and radii, that were left out of the original designs for the sake of modeling and simulation ease. Dies will then be retested and further work will be performed in the area of die force reduction via optimal die and billet design. The optimally designed dies will be manufactured and Queen City Forging will experiment with the new dies to test the validity of the simulations.

Conclusions

The 3D modeling with Solid Edge and Mechanical Desktop as well as the simulation with SuperForge has been a success. Many sets of dies and test billets were created and the forging and bending processes were performed. The bending and forging operations from the SuperForge simulations seem to give the desired results. The entire forging process can be completed using three steps, which are the bending operation and a blocker die and finisher die. Queen City Forging is currently using five steps including bending, 2 flattening, a blocker and finish forge. The new designs of the dies have shown to reduce the number of steps to three, which in essence can reduce the cost of the dies and time required to produce the final part thus reducing the overall manufacturing cost per part. The best billet and die combination is the second set of closed dies with 5-18-01 test 1 billet.

References

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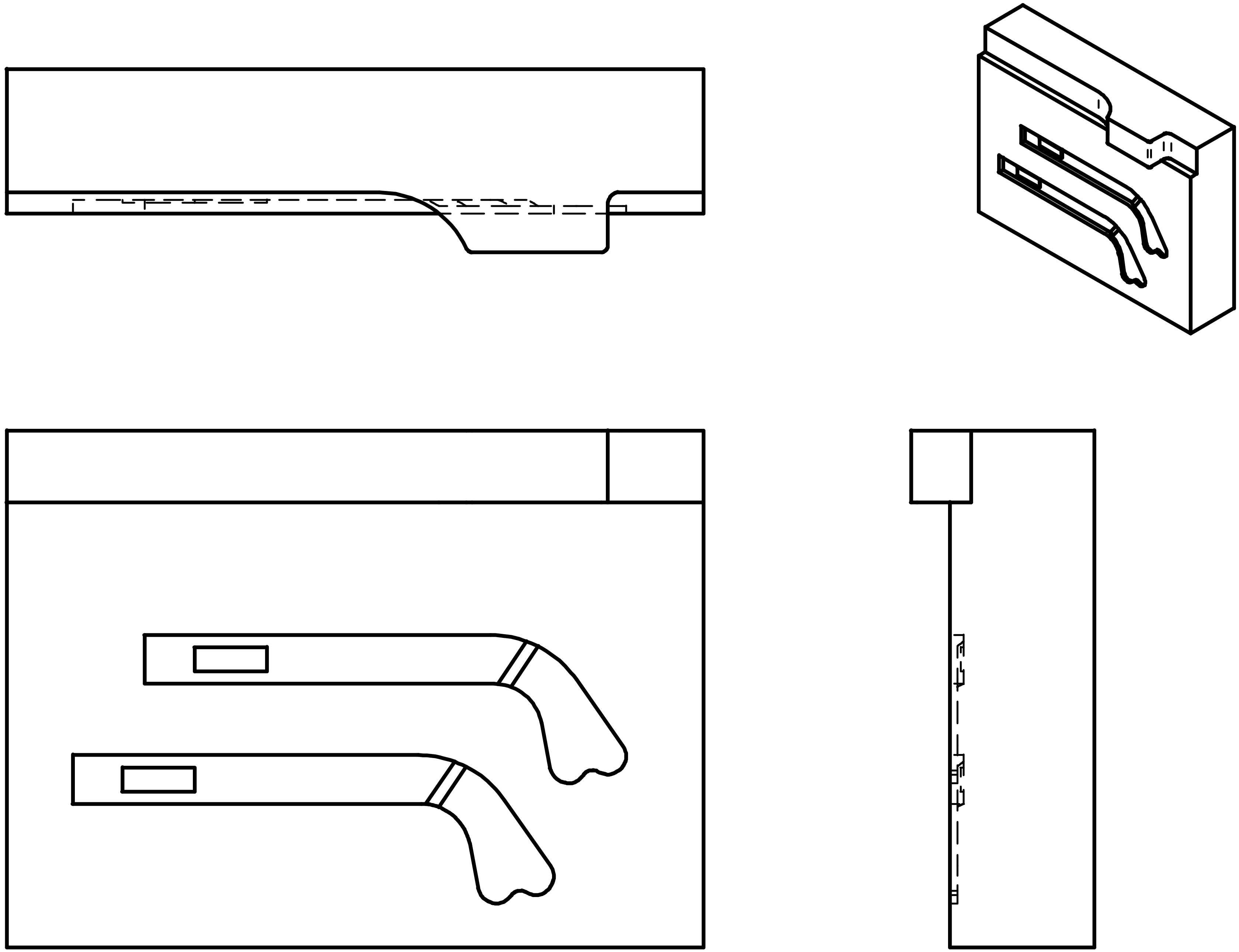
Kalpakjian, Serope. Manufacturing Processes for Engineering Materials, 3rd ed. Addison-Welsley: Menlo Park, California. 1997.

Queen City Forging. http://www.qcforge.com. 7th June 2001.

APPENDIX



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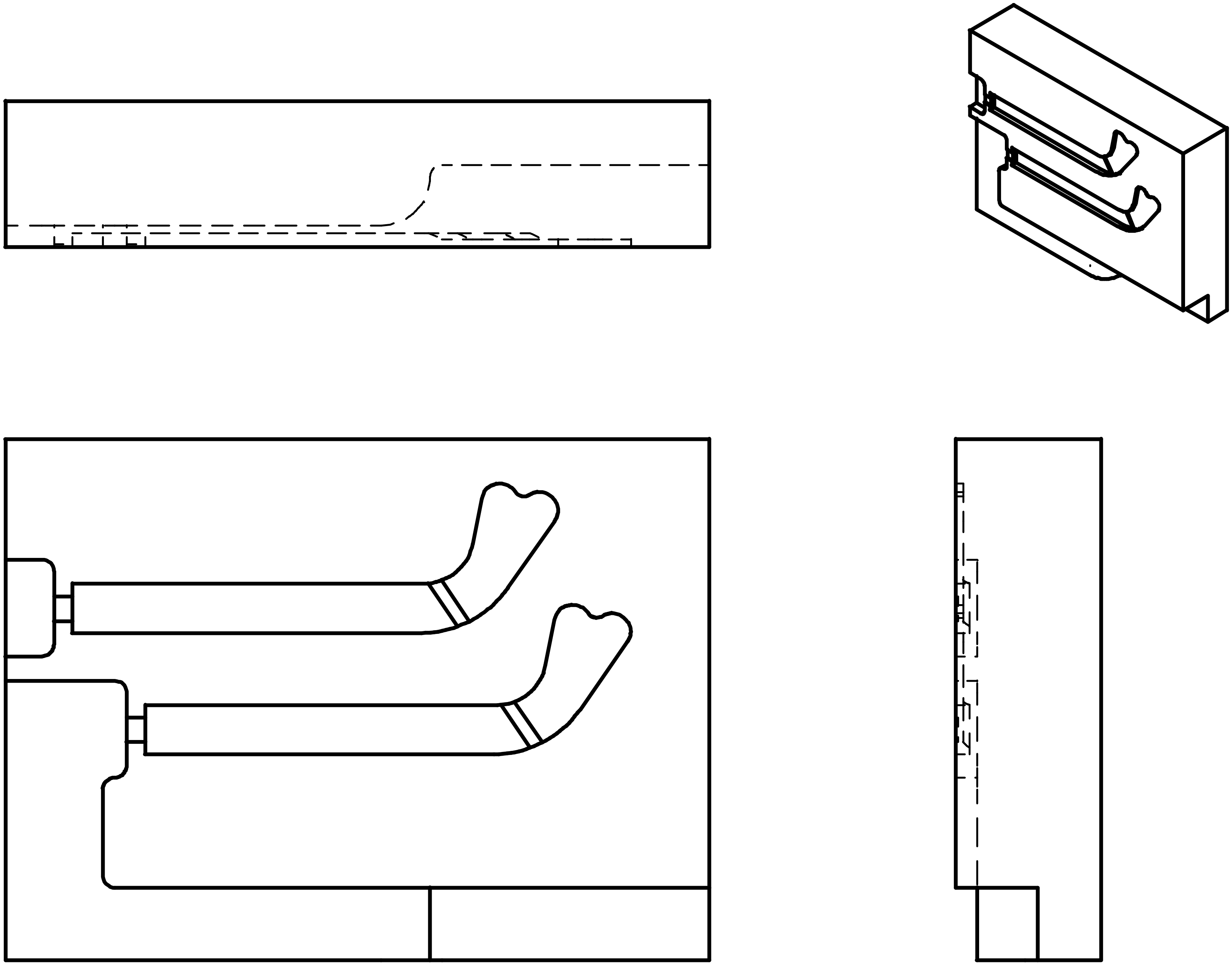
Project manager: Dr. Jay	Designer: John Rankin



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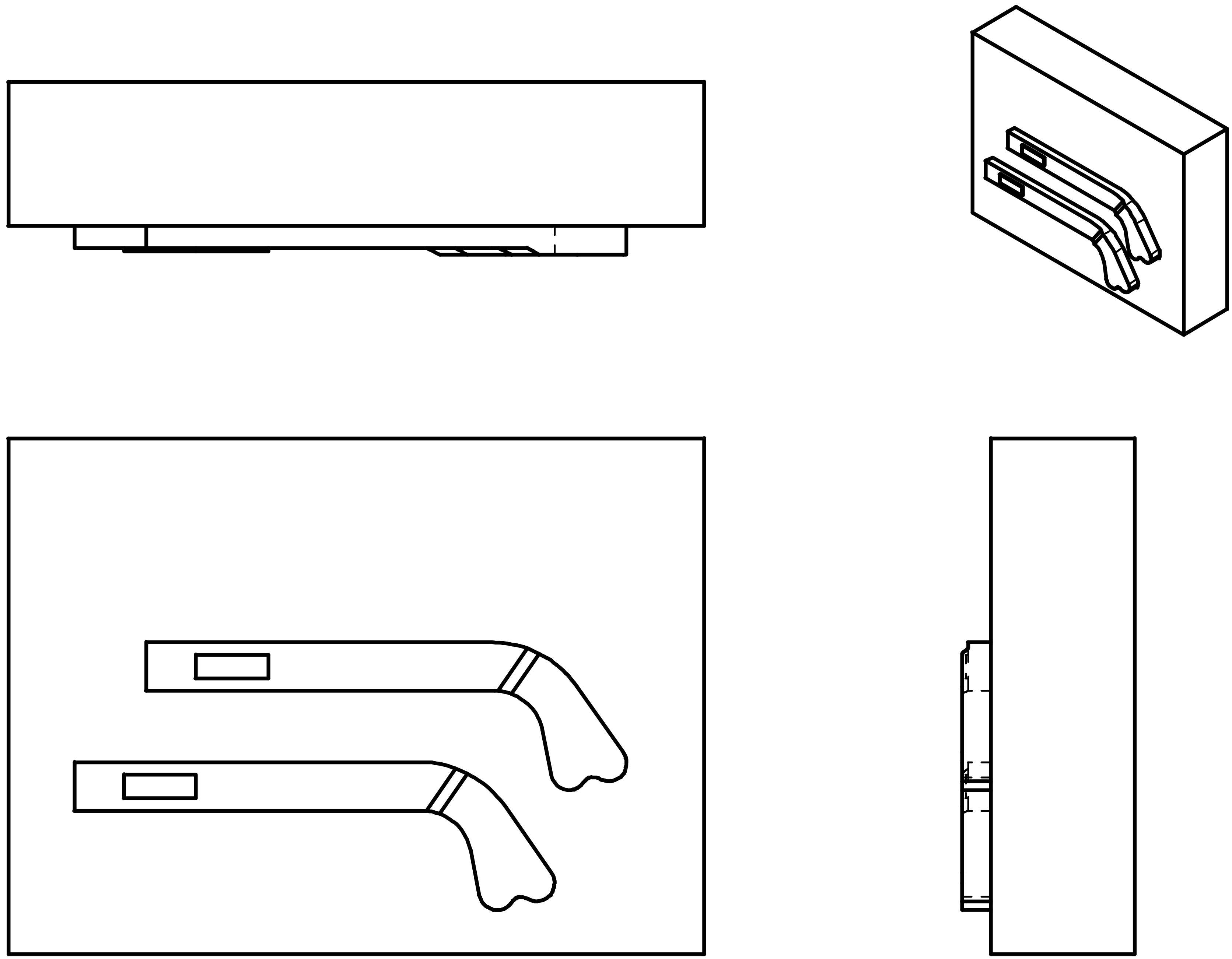
Project manager: Dr. Jay	Designer: John Rankin



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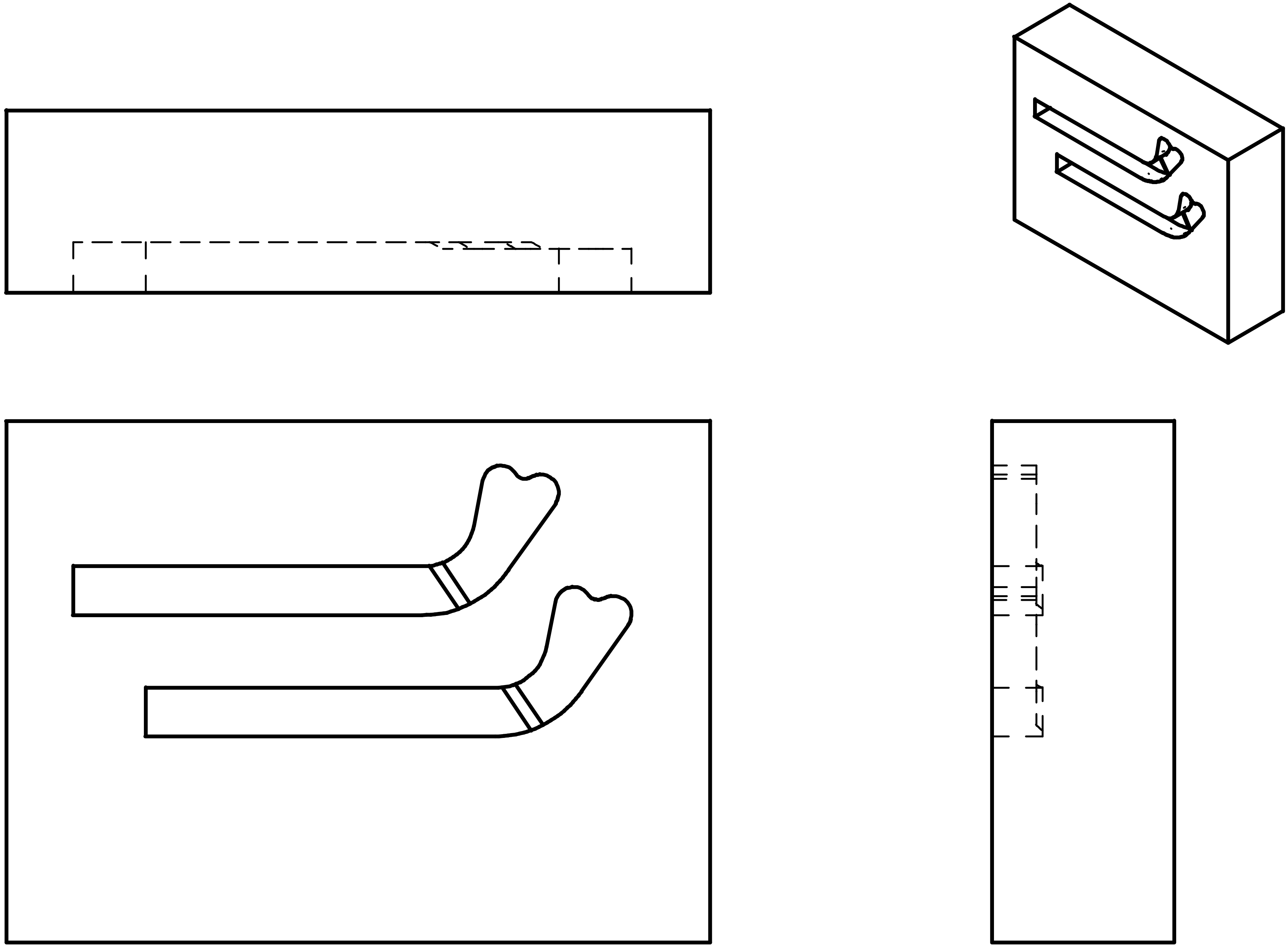

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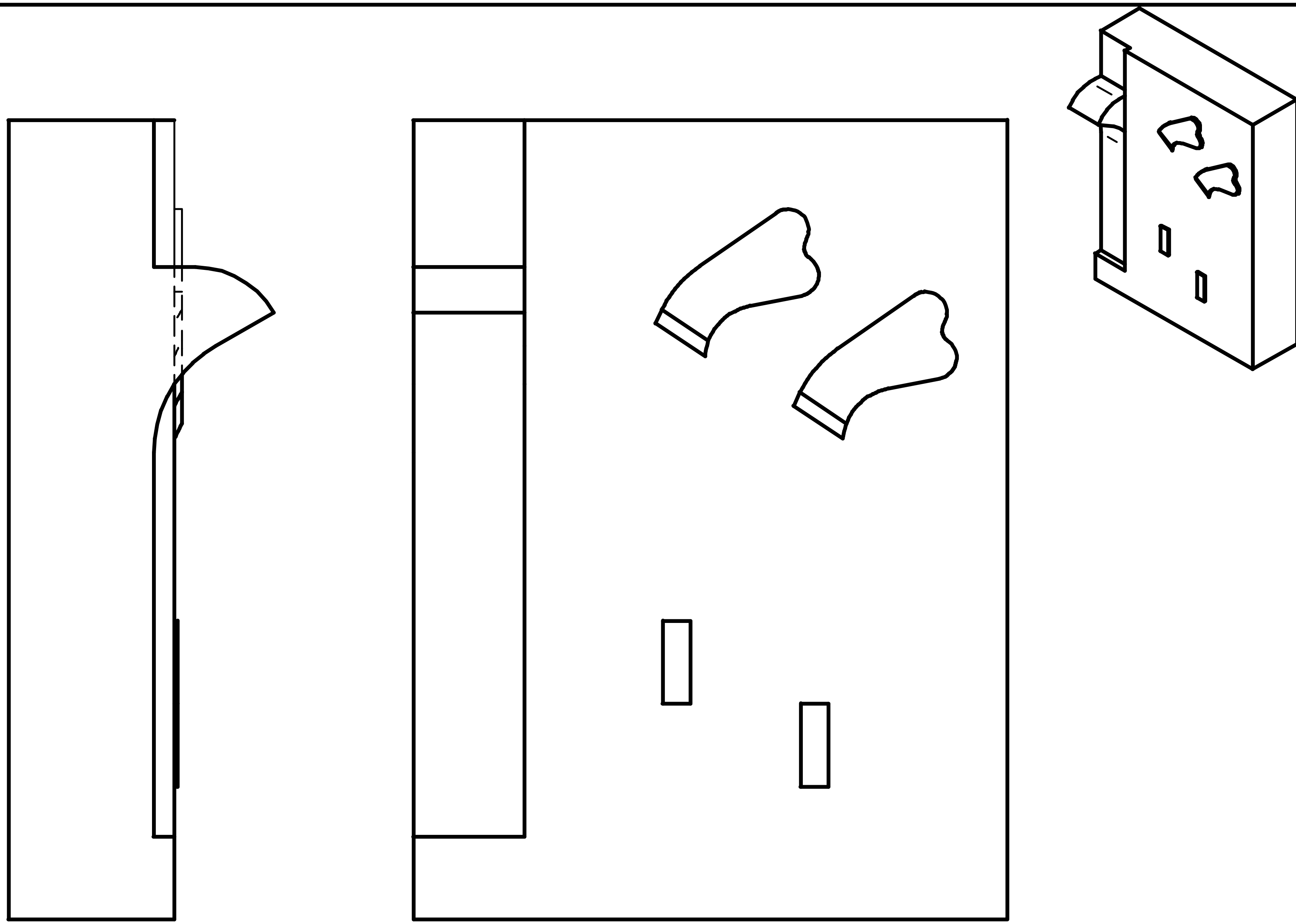

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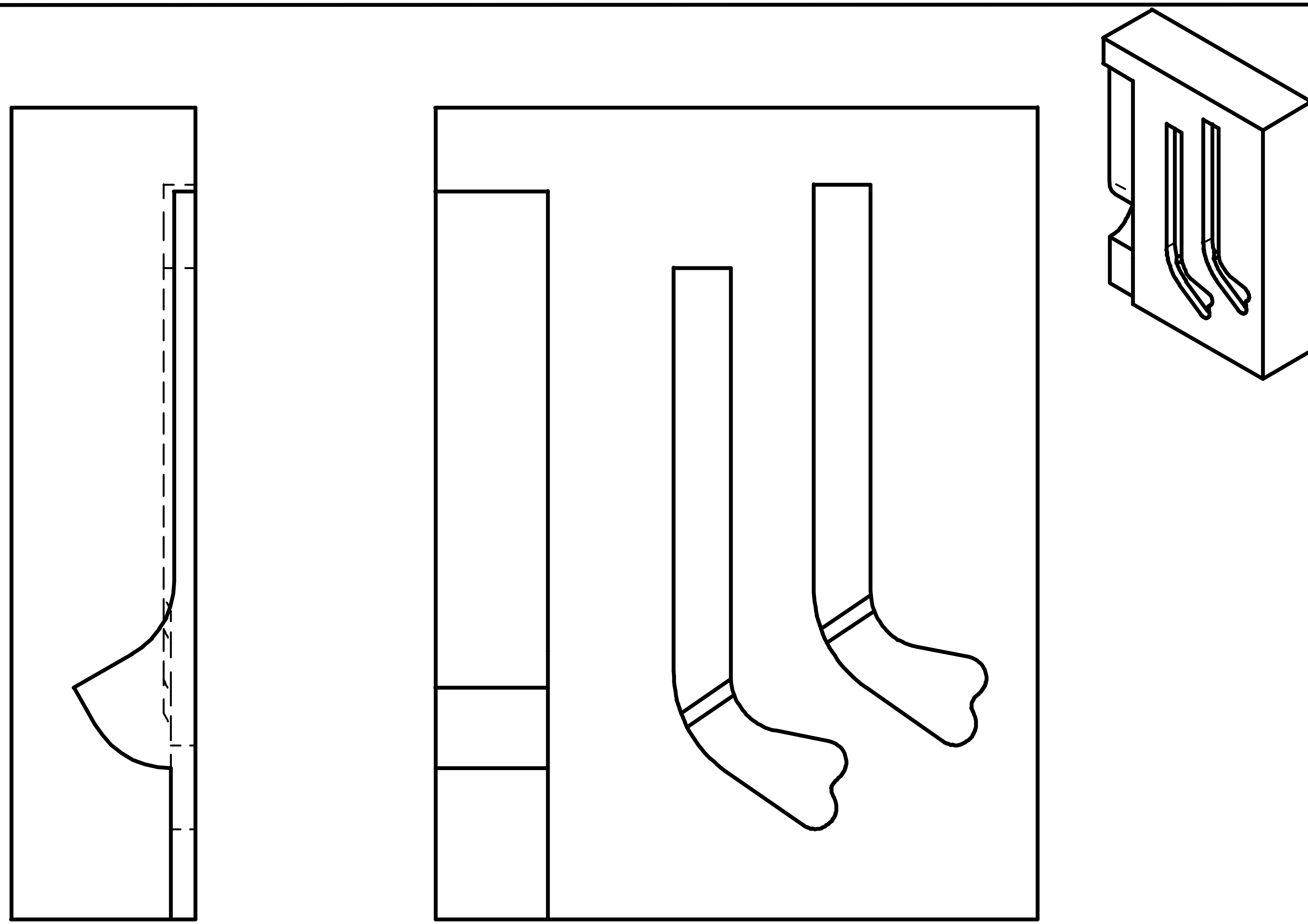

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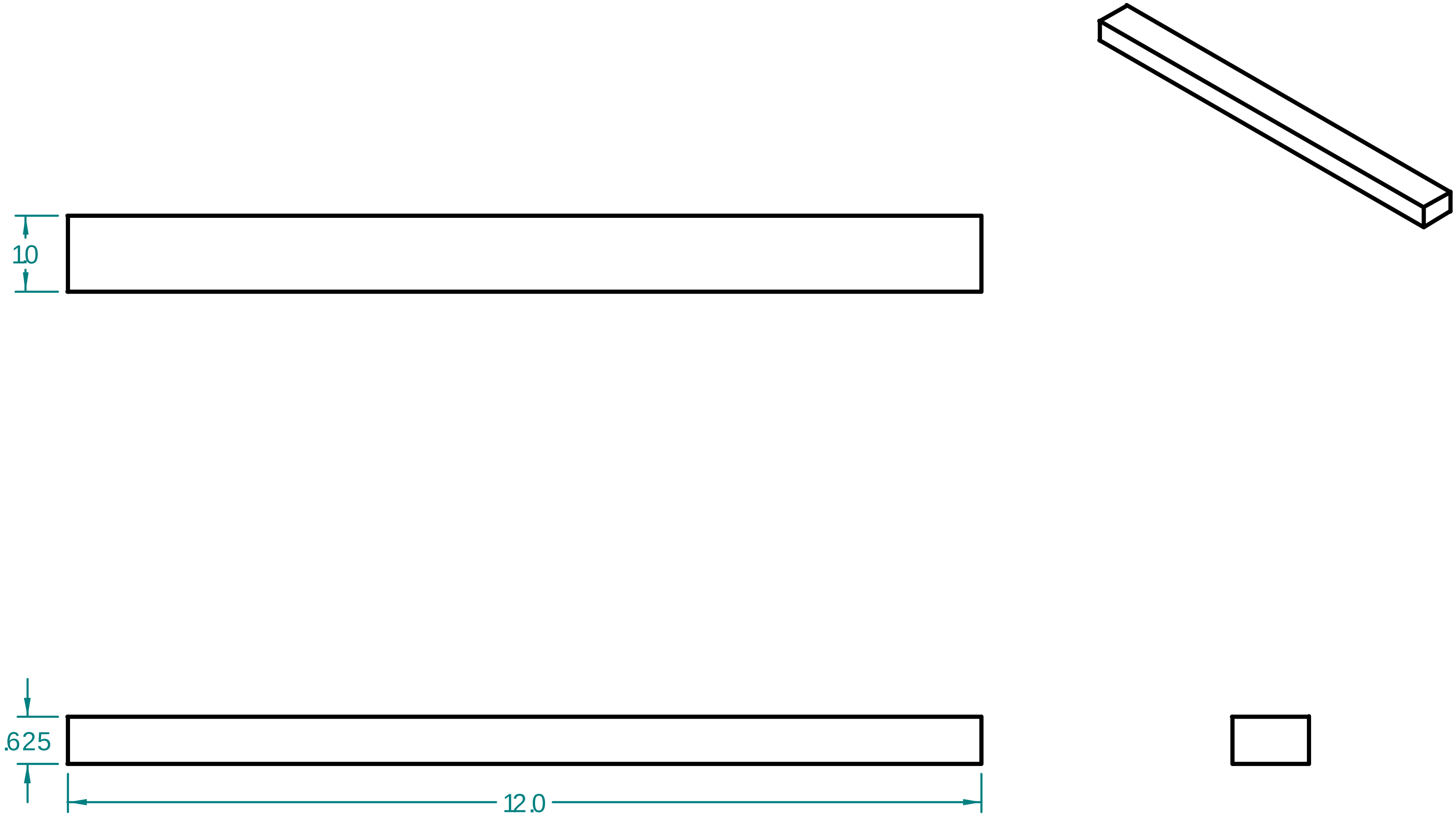

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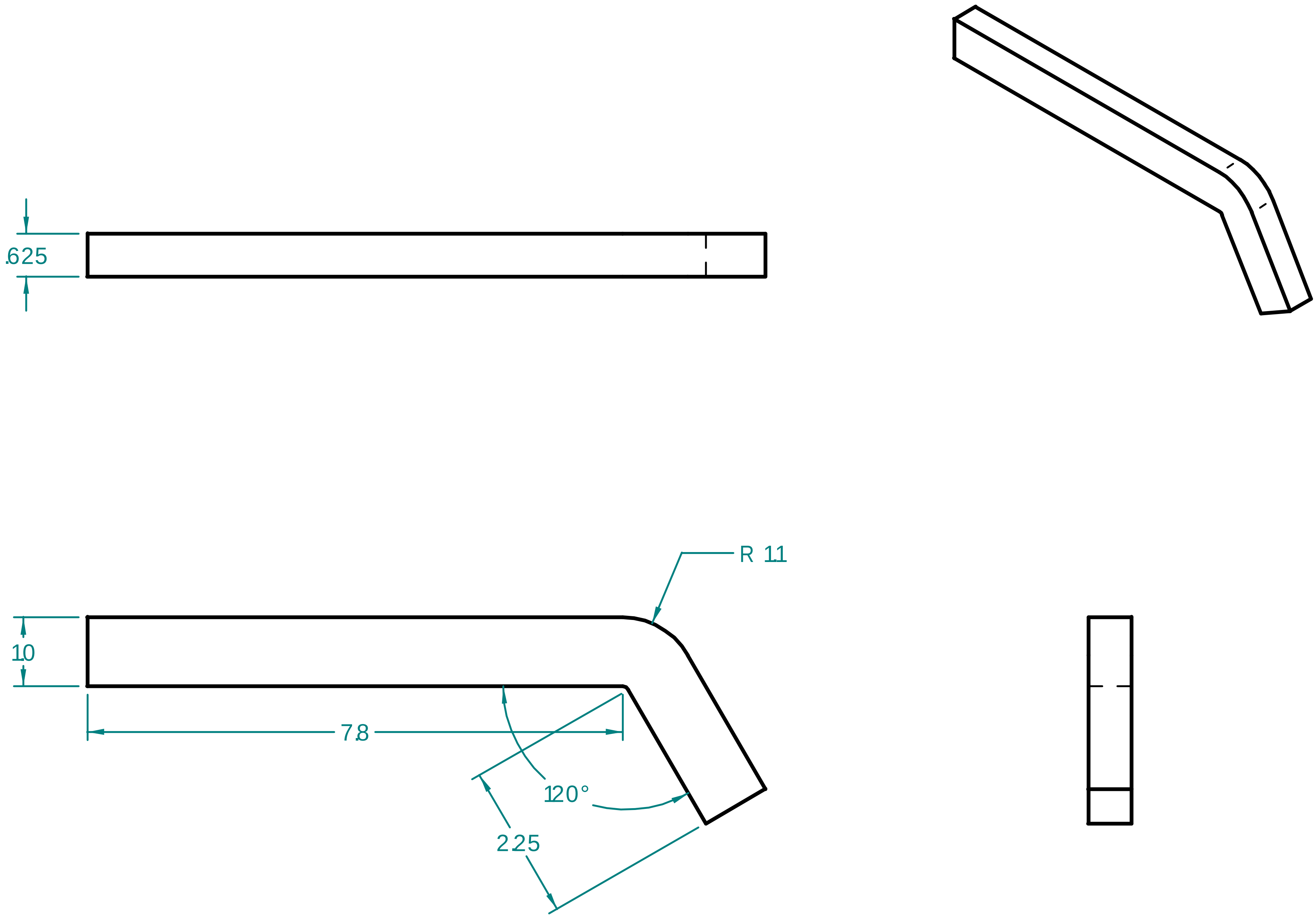

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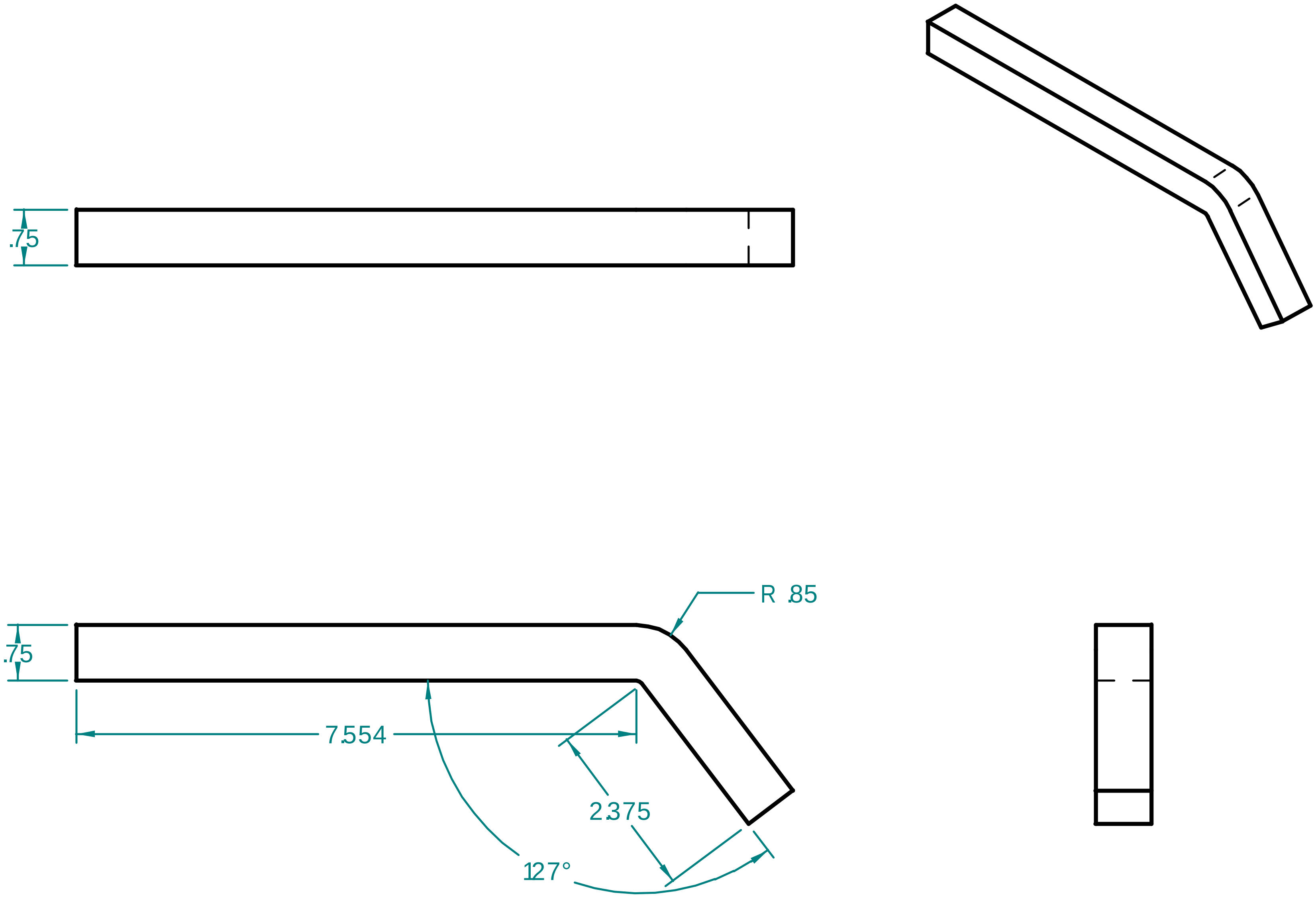

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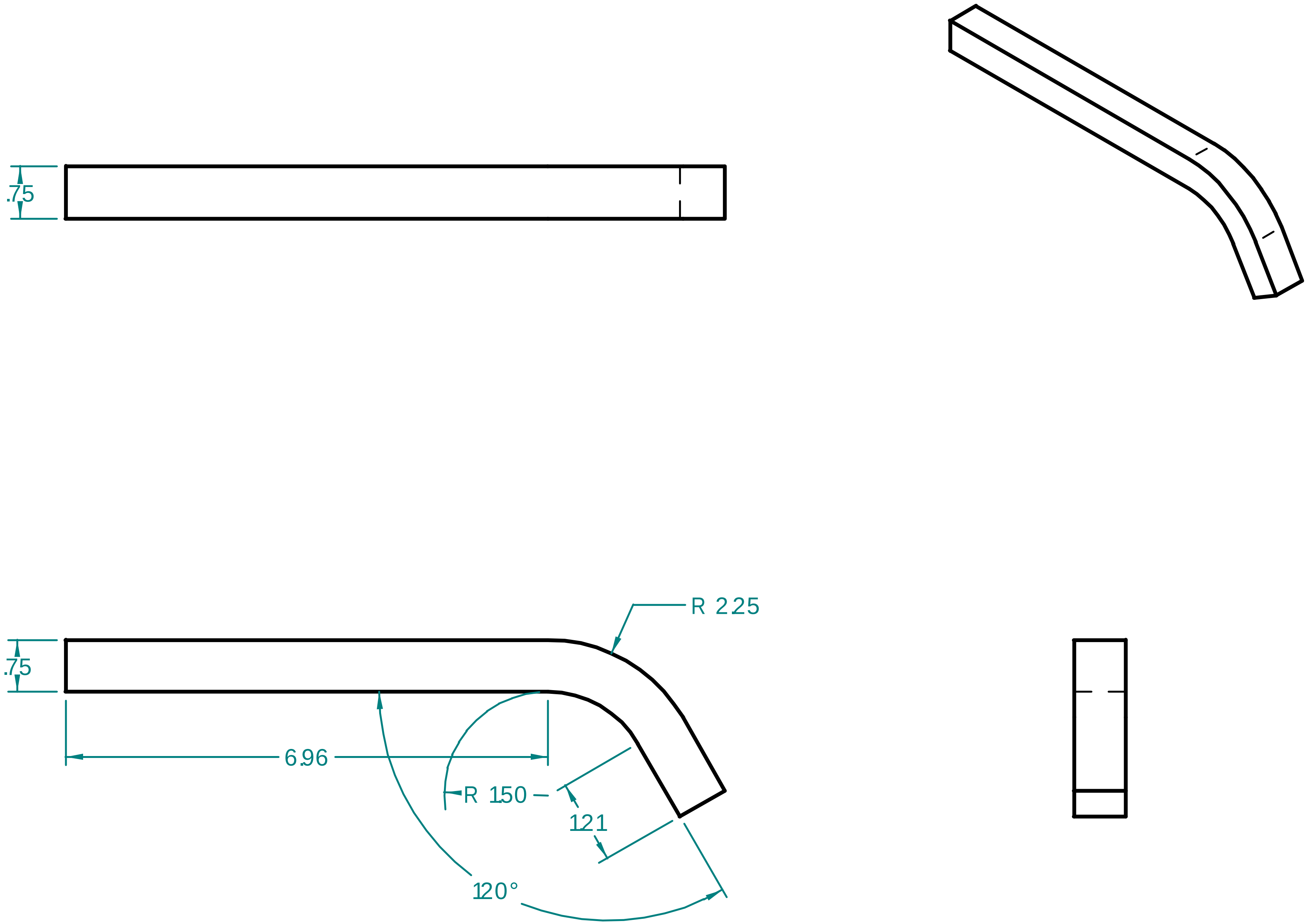

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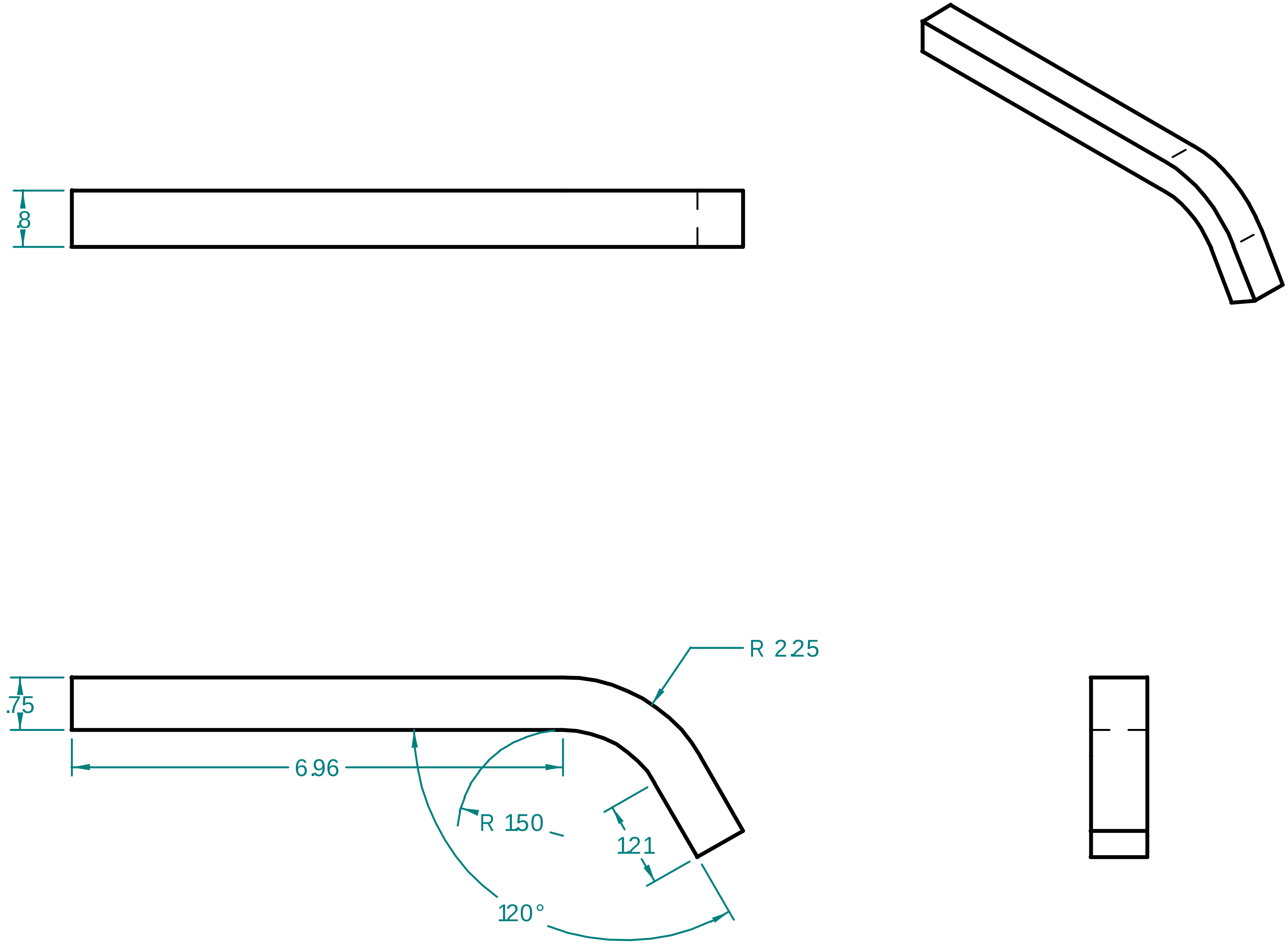

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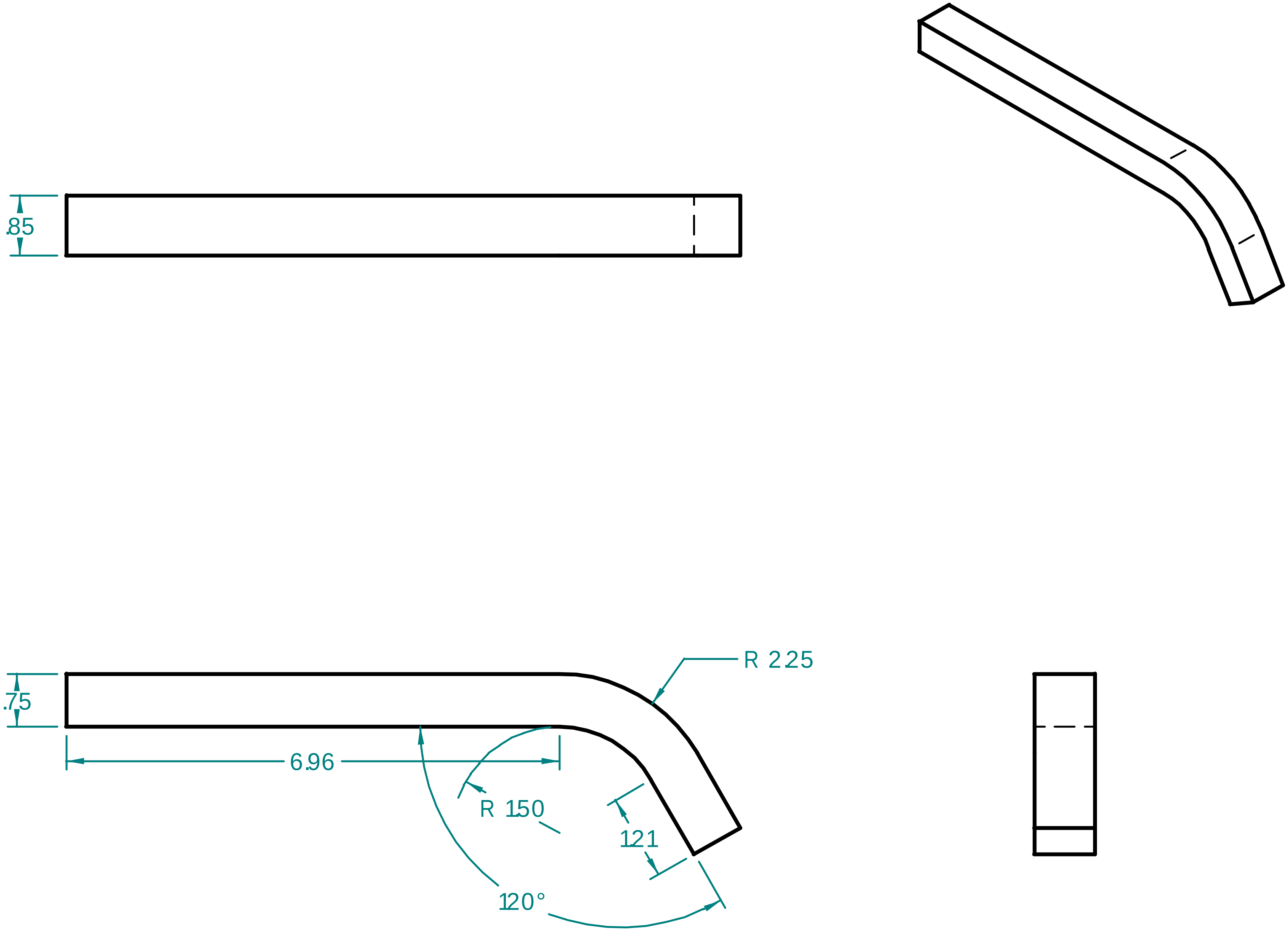

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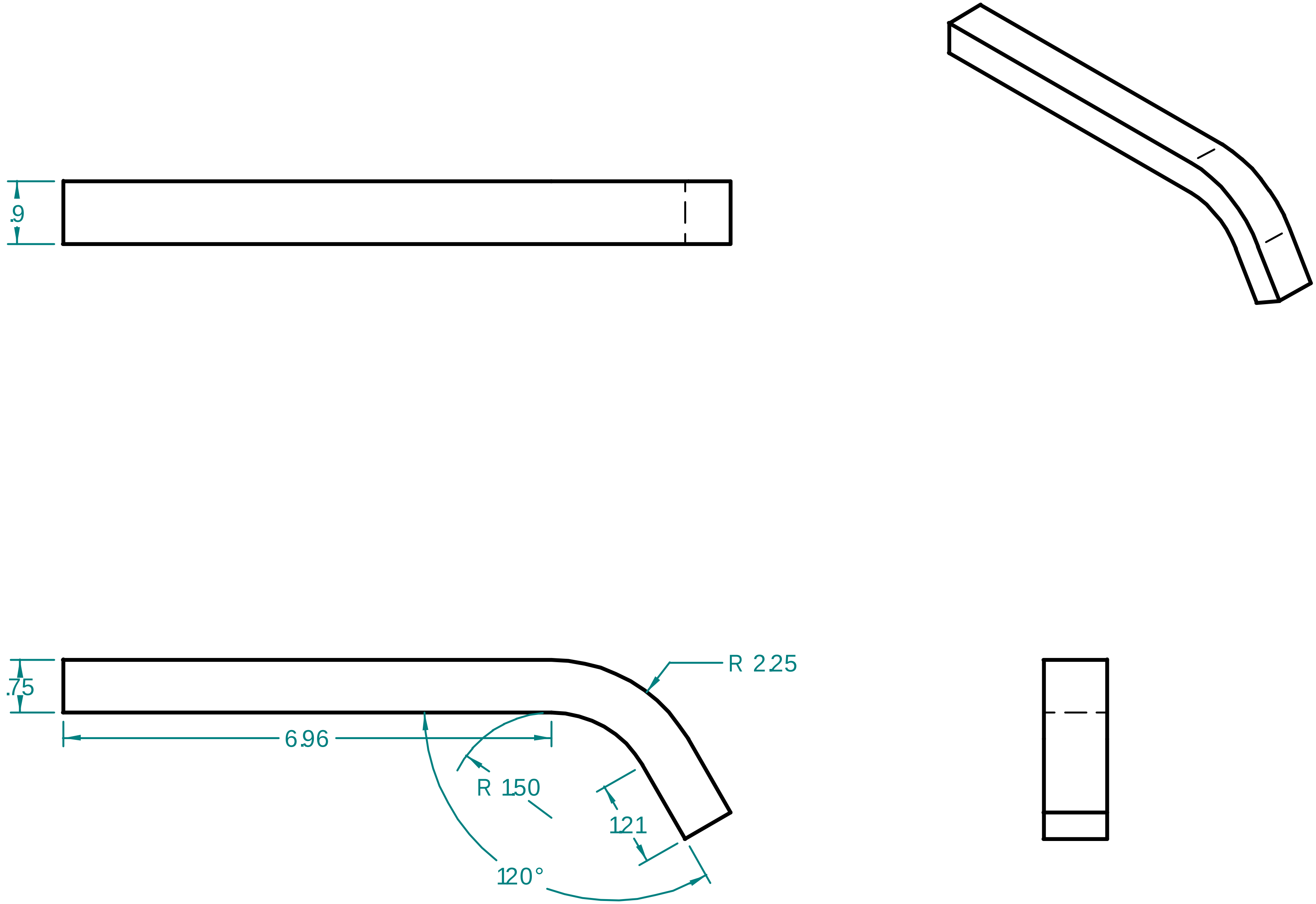

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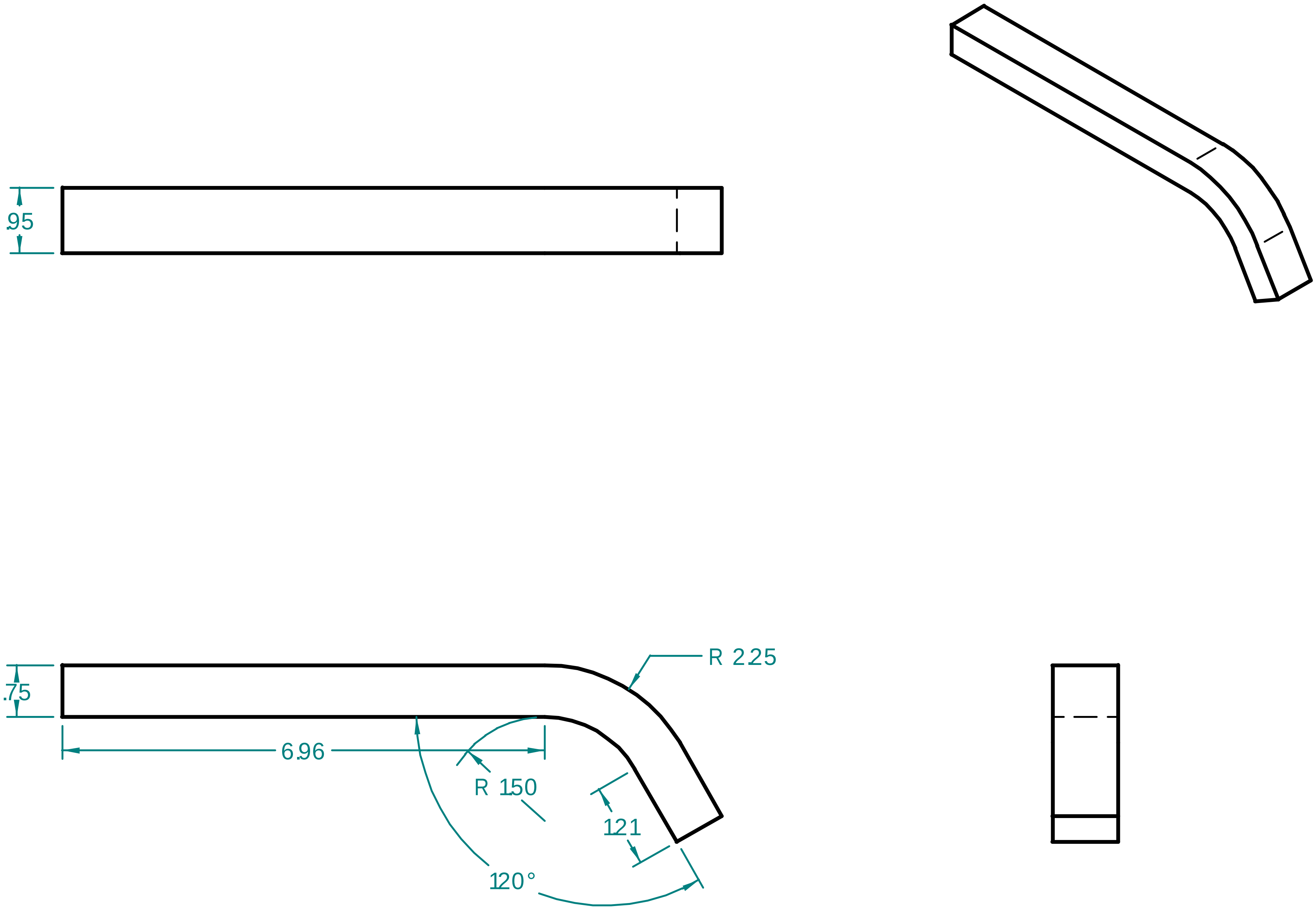

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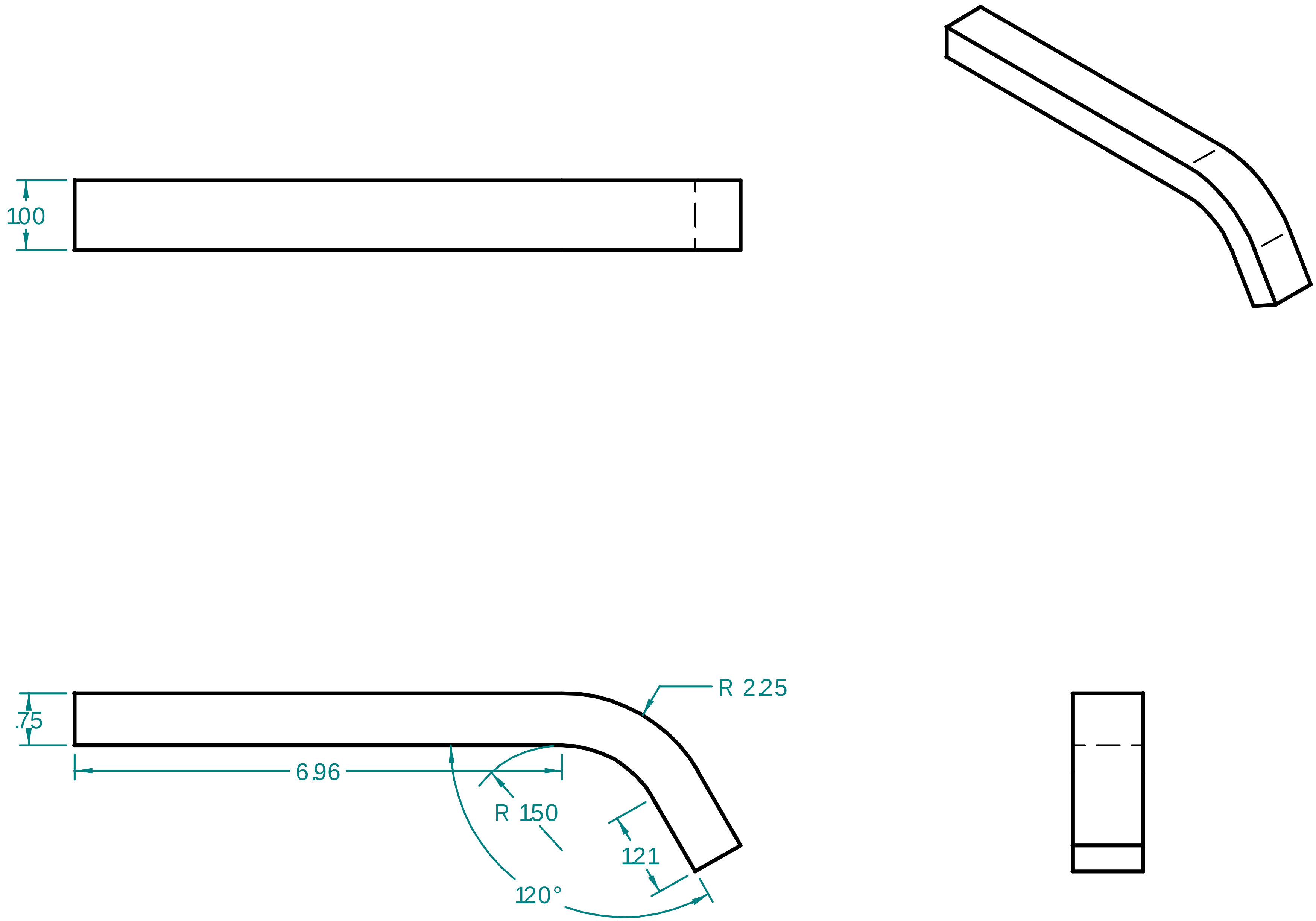

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