

# MAKE YOUR OWN PROTEIN SCULPTURE

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ABSTRACT. This paper explains how to make mitered-cut wood or steel sculptures of proteins using cutting data calculated with my program "Mitre" from structural protein data contained in .pdb files or any other set of three-dimensional points. Please feel free to contact me to get the necessary cutting instructions.

## 1. WOOD

The entries in the list of cutting instructions look like this for each cut:

0 5(5.34/16) nu1,2: 2(33.4/64), 1(32.8/64) alpha: 76.6 beta: 46.5  
I: 7(13.7/16) II: 6(13.5/16) III: 2(13/16) IV: 3(13.2/16)

"0" is the number of the cut 0, 1, 2, ...,  $NUM-3$ , where  $NUM$  is the number of points connected by the sculpture (Number of the  $C_\alpha$ ). Cut  $NUM-2$  is the last one, therefore perpendicular to the material. The next two numbers are normally not used: "5(5.34/16)" is the position of the center of the cut measured from the front end of the material and "nu1,2: 2(33.4/64), 1(32.8/64)" are the four distances from the center along the edges of the material (see Fig. 1b).

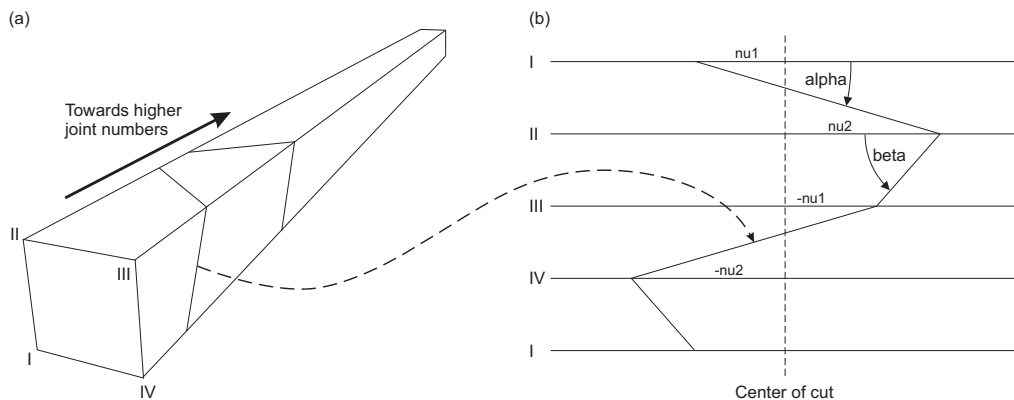


FIGURE 1. The numeration of the edges (a) and the material unfolded (b).

To start, the edges on the material have to be marked I, II, III, and IV. This needs to be done as shown in Fig. 1a. A different sense would result in the mirror image of the intended structure. A tape measure is placed on each edge and all distances are marked. The first mark on edge II is in our example at "II: 6(13.5/16)", that means, 6 inches and 13 1/2 sixteenth of an inch, or approximately 6.84 inches in decimal.

One set of four such marks gives one cutting plane. After all edges are marked it makes sense, especially for larger projects where the errors accumulate stronger, to check and to improve the accuracy of the angles with a protractor. On the face between edge I and II the angle is *alpha*, in our example  $76.6^\circ$ . The same angle is found on the opposite face, and the remaining two are given by *beta*. The angles are defined such that  $90^\circ$  is a cut perpendicular to the edges. A power saw can be used but it cuts away a lot of material at differing angles, which results in a slight change of the geometry (non-constant length of peptide units) and, worse, the accuracy is poor. Ideal are the Japanese hand saws which cut on the pull stroke. After carefully starting each cut making sure the saw is on the right track it will keep the direction very accurately, resulting in planar cuts and therefore sound joints. The piece is then assembled according to Fig. 2e–f, i.e. that edge I connects with edge III, and edge II with edge IV. Ordinary wood glue works fine, but since clamping is impossible, it is important to press the pieces together for about a minute before putting them into a drying position which should exert a minimum amount of force on the joint. It is practical to glue a sculpture in sets of two pieces first. Then two couples can be combined and so forth, until the two remaining pieces get glued together. This last joint typically demands building complicated contraptions to hold the pieces in place. When dealing with a protein consisting predominantly of beta sheets (for example GFP or my virus capsid) it makes sense to assemble the beta sheets first, and correct for errors while assembling the sheets.

## 2. SQUARE METAL TUBING

The principle for making proteins from square tubing is the same as described above, with the additional complication that the cuts are done perpendicular to the faces of the material<sup>1</sup>. It is not sufficient to have four cuts per joint, because then the pieces do not fit together upon reassembly. Instead, four additional cuts have to be done along the projection of the calculated cutting plane hitting the interior surface

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<sup>1</sup>For two reasons: It allows for the use of devices like plasma cutters, and it provides room to weld the pieces.

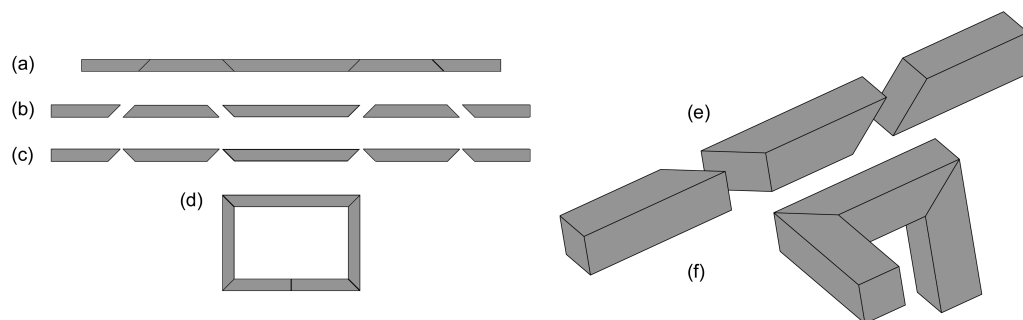


FIGURE 2. A picture frame is constructed by cutting a one-dimensional piece of wood (a) at  $45^\circ$  (b), flip every other piece (c), and reassemble the pieces in the same order (d). Mitered cuts can be applied such that the material (e) occupies all three dimensions after reassembly (f).

of the tubing. For projects using large steel beams my program can calculate the position of those additional cuts. If the width of the cut (about  $1/16''$  (2 mm) for a plasma cutter) is larger than a typical distance between the calculated cutting plane and the projection on one face (maximally about  $\sqrt{2}$  times the wall thickness of the tubing) the removal of material can be used to reduce the number of cuts to four. In that case it is important which side of each cutting line needs to be preserved and on which side material is going to be removed. Fig. 3 explains the geometry which is very easy to apply in practice.

A ruler attached to a strong magnet is a useful device for making accurate plasma cuts. I use a piece of wood planed to the distance between the ruler and the location of the actual cut to determine the position of the ruler.

I found it easiest to weld the pieces together by starting with a tack weld at the innermost corner to position the pieces and then weld the two seams around the outermost corner shut.

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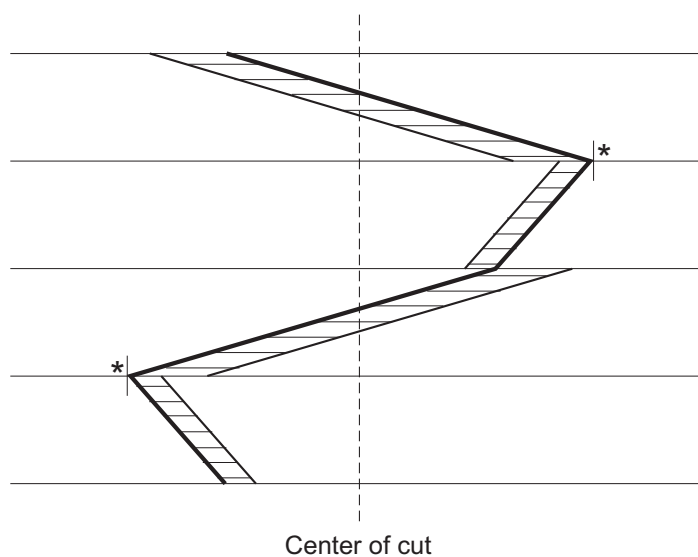


FIGURE 3. This is essentially the same image as Fig. 1b. The thicker line is the calculated cutting plane. If the cuts are placed such that the material is removed where the hatched areas are, the pieces will fit together perfectly and leave a gap ideal for welding. The hatched areas are always facing away from the points of furthest distance between the center of the cut and the cutting plane (marked with \*).