Theoretical developing of domestic 3d printing culture.

Use of nozzle tip as height sensor with a rocker arm mechanism

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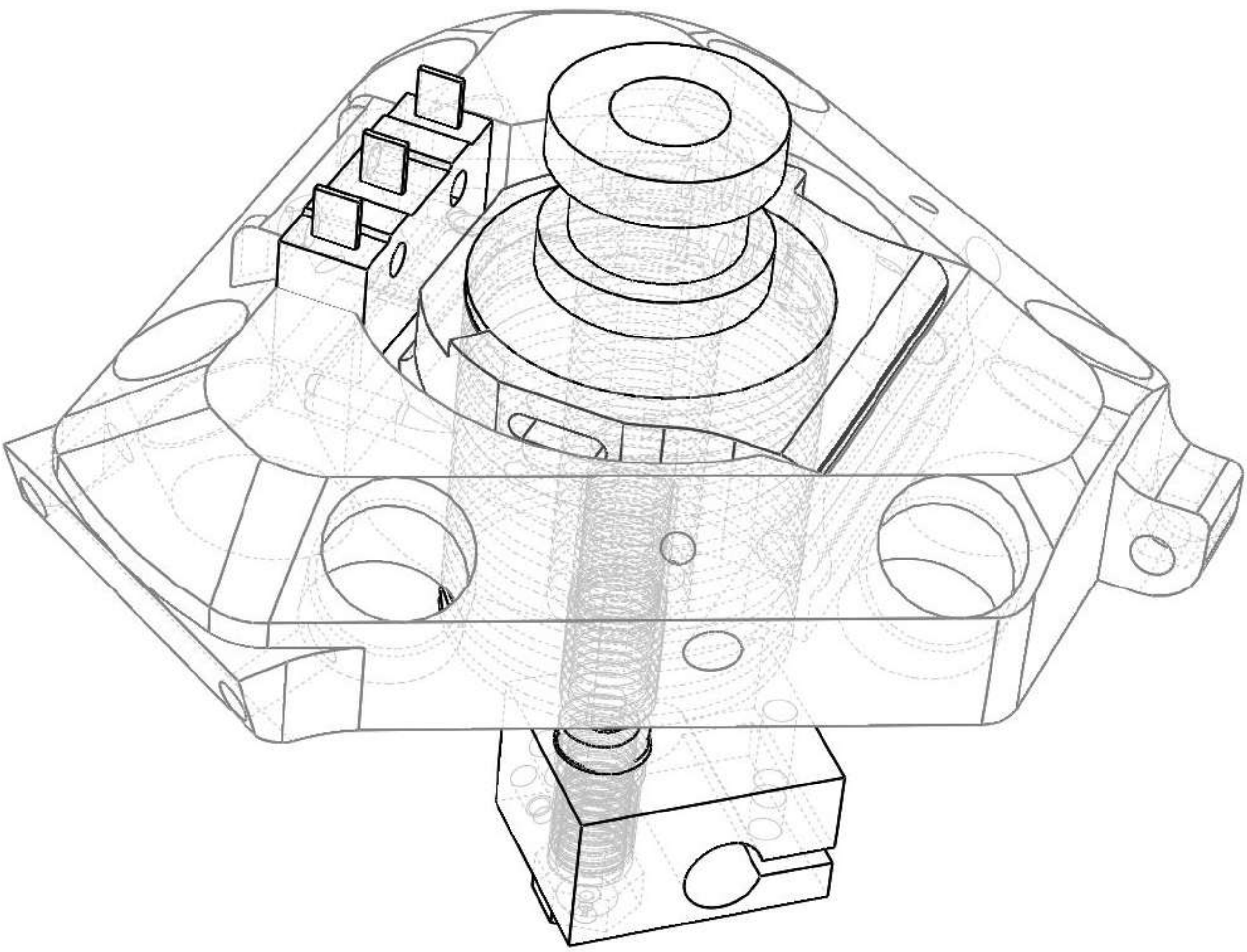

Contents

1 INTRODUCTION **2**

2 EXPOSITION OF MECHANISM **2**

2.1 Analysis of associated error. 3

2.1.1 With exact dimensions. 3

2.1.2 With un-exact dimensions. 3

2.2 Example. 4

3 Technical optimizations. **4**

3.1 Design of the axis. 4

3.2 Ensuring perpendicularity between rocker and hot end. 4

3.3 Fixing the rocker while printing. 5

4 IMPLEMENTATION OF THE AUTHOR **5**

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Summary

Height measuring is a very important task for our domestic 3d printers. But implementing a sensor on our print head is usually expensive and laborious. Also those measuring methods are ruled by the geometric error of the implementation. In this paper a simple and cheap mechanism is analysed and optimized. Also an example of implementation is explained.

1. INTRODUCTION

Height measuring is essential for a domestic 3D printer. The automation of bed calibration makes the process of printing less laborious and faster in general. Nevertheless most of height detection systems for delta printers are expensive, problematic to implement and usually they accumulate several dimensional and geometric error.

For example, any kind of switch deployed on ex-centric point of the delta head accumulates the error of several moving parts, elasticity of the rods and the dimensional error of the pieces. It also multiplies the parallelism error of the head and bed.

In this article a simple and accurate mechanism which only needs of an end-stop switch and a rod/long screw. This mechanism uses the tip of the nozzle as the end-stop activator so the angular error of the head is not multiplied and no elasticity interferes.

Reader could wander if the fact of mixing the hot end with moving parts may introduce vibrations, this is of course discussed in this article and is shown by the logic and experience that this is not a major problem.

Some already tried an implementation of this idea, one of the first examples I know is the creator of "Cerberus" delta printer, Steve Graber. In my opinion the implementation of Cerberus was a failure because of the weak axis joint designed for the rocker mechanics, the tiny length used to fix the axis made link to loose and impossible to build with printed pieces.

2. EXPOSITION OF MECHANISM

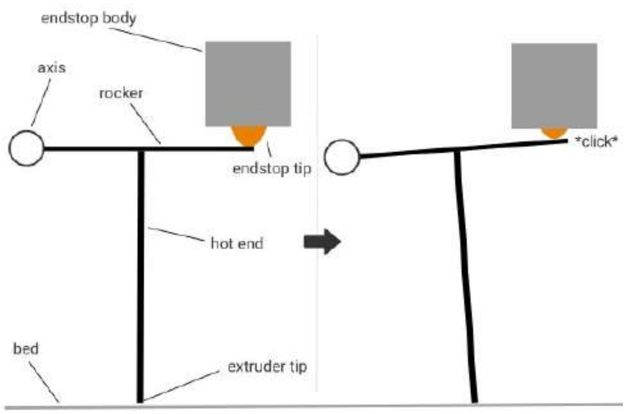

Figure 1: Mechanical scheme of the mechanism after and before switching.

Figure 1 shows in a simplified way the mechanism before and after pressing the end-stop. First of all we should stablish the relationship between distances d and $d*$ shown on figure 2.

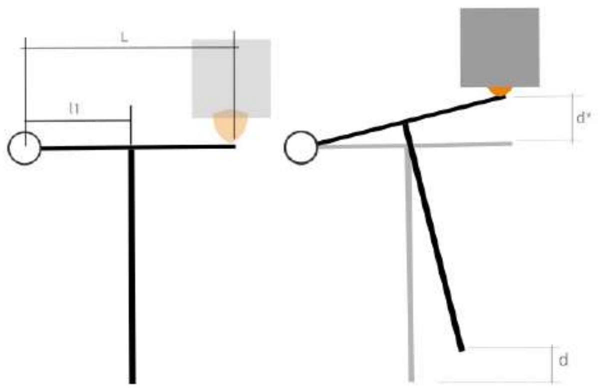

Figure 2: Geometric parameters of the mechanism, d and d^* represent distances at the moment of end-stop switching.

It is easy to find the next relation:

$$d = ad^* \tag{1a}$$
$$a = \frac{l}{L} \tag{1b}$$

Last equation give us an idea of the small distances implicated on the measuring mechanism. To avoid angular error it is good to look for a distance d small as possible. This could be archived if the resting distance of the end-stop tip and the rocker is small as possible. This optimization will be analysed in further sections.

2.1. Analysis of associated error.

First of all we should calculate the associated error to this mechanism related to the error committed by the switch and structural pieces of the mechanism. For this I should remember this expression for the calculus of associated error of a variable which depends of n variables.

$$\triangle\alpha(\bar{x}) = \sum_{i=0}^{n} \left|\frac{\partial \alpha}{\partial x_i}\right| \triangle x_i \tag{2}$$

First of all I'll calculate the error assuming dimensionally perfect structural pieces.

2.1.1. With exact dimensions.

Applying expression 2 to 1 we get onto the next which implies only the switch distance error given by the manufacturer.

$$\triangle d = a\triangle d^* \tag{3}$$

2.1.2. With un-exact dimensions.

$$\frac{\triangle d}{a} = \triangle d^* + d^* \frac{\triangle l}{l} + d^* \frac{\triangle L}{L} \tag{4}$$

It is a common situation for printed pieces that the associated error is equal and constant for every length at the same plane and direction, this means that usually we'll find that $\triangle l = \triangle L$ and equation 4 becomes the next:

$$\frac{\triangle d}{a} = \triangle d^* + b\triangle l \tag{5a}$$
$$b = \frac{d^*}{L}(\frac{1+a}{a}) \tag{5b}$$

We could also linealize expression 5b assuming a value of a close to 0.5, which is a common value.

$$b \approx \frac{d^*}{L}(5 - 4a) \tag{6}$$

The conclusion derived from the last operations is that the error introduced by the dimensional imperfection of the rocker mechanism is proportional to the distance d^* that the switch travels and proportional to the inverse of rocket length.

2.2. Example.

Let's see some common values for those distances and their associated error. Note that d^* is the sum of provided switch displacement and the distance between the tip of the switch and rocker.

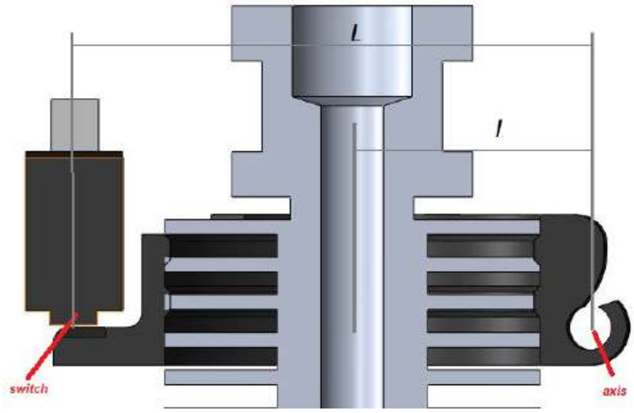

Figure 3: Section view of my implementation of this mechanism of my own 3D printer.

My particular implementation uses the next dimensions, I'll be conservative with the errors and suppose the worst situation:

- $L = 35.88 \pm 0.30mm$
- $l = 15.75 \pm 0.30mm$
- $d^* = 0.6 \pm 0.17mm$

So, making the calculations we obtain the next results:

- $\triangle l = 0.3mm$
- $\triangle d^* = 0.17mm$
- $a = 0.44$
- $b = 5.42 \cdot 10^{-2}$
- $d = 0.26 \pm 0.08mm$

As we can see, for usual magnitudes $\frac{\triangle d}{\triangle d^*} \approx a$. Assuming only the errors introduced by this phenomena we discussed, the mechanism is a clear win for precision. Assuming no error because discretization of motion (this is actually a realist assumption because of micro-stepping) this is the error we're going to commit when measuring bed height, indeed this is the precision error I usually obtain when calibration. Nevertheless several technical details should be take in care. Those will be discuss on next chapter.

3. Technical optimizations.

This mechanism is cheap and accurate, but it absolute needs to be implemented following some technical requisites.

3.1. Design of the axis.

The Axis is a very sensitive part. Any slack could introduce strong vibrations into the nozzle and ruin your print. It also should resist over time without becoming loose.

The main idea to archive this is to make a long axis with an elastic fitting. Figure 3 should be an example of this. The elastic fitting is necessary to absorb the imperfections of the printed piece. Imperfections are part of the equation and should be taken in care.

3.2. Ensuring perpendicularity between rocker and hot end.

When fixing the hot-end to the rocker, is important to ensure that the geometric relation between the pieces is the one you were expecting to be. Usually you are going to use a perpendicular relation between the rocker and the hot-end. The way I made it sure can be seen on figure 4. Some rocker circles the heat sink of the hot-end with some stripes to fix is in an exact position.

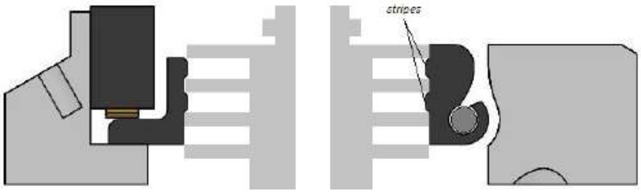

Figure 4: Slice view of my implementation.

3.3. Fixing the rocker while printing.

Of course moving parts on the delta had may introduce problems on the printing, that's why you should add some method to fix everything on place. I personally use a screw that press the rocker over the resting point.

4. IMPLEMENTATION OF THE AUTHOR

The results of me applying this theory on a real design can be seen on figures 5 and 6.

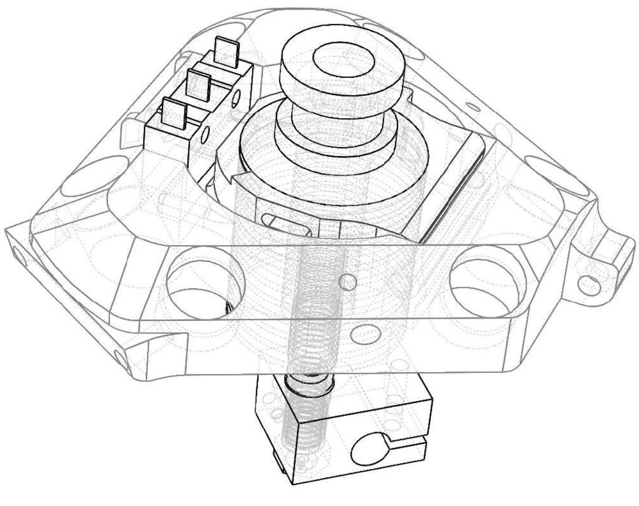

Figure 5

As can be seen, the rocker is also a clamp that fix on the hot sink. This clamp is tensioned with two screws. The tension may blend the rocker a little, so it's important to add some weak points that absorb the elastic deformation. The end-stop is fixed with two M2.5 screws to avoid any movement.

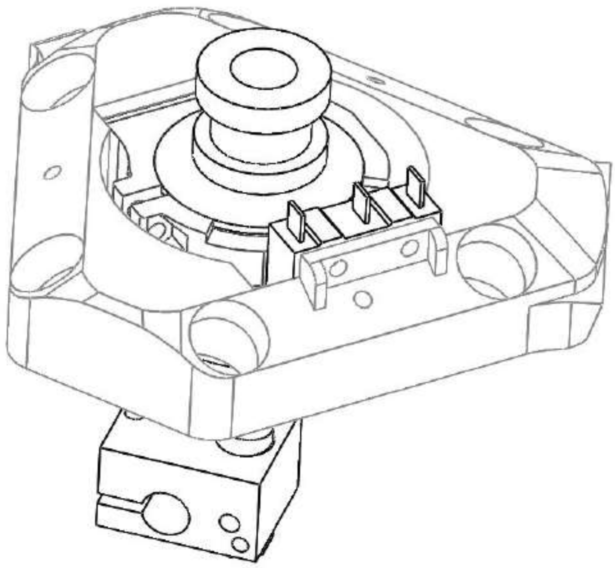

Figure 6: 3D view of my design of delta head.

The main problem with this design is the assembly and dis-assembly for maintenance. Also the axis is a very sensitive part, if the joint between all the pieces is not strong enough, time may generate vibrations because loosen pieces.

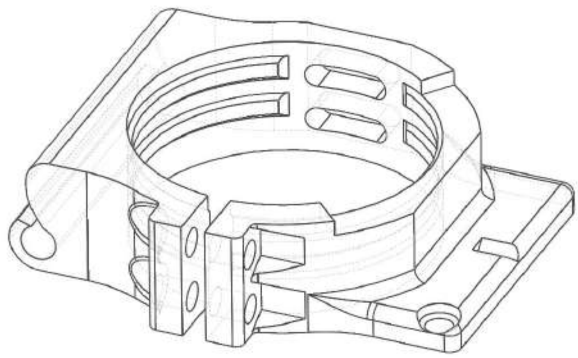

Figure 7: 3D view of the Rocker/Clamp.