# HAND BENDER FOR GUTTERS HOOKS

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This paper represents results of student project. The main goal of this work was to redesign and construct hand controlled machine to bend gutter hooks. Hand bender for gutters hooks is used by plumbers' shops. Redesign of the hand bender is processed with several improvements. The whole process of construction is described in this work. From the introduction to the bending technology, choosing the most optimal construction variant of the other mentioned benders, to final dimensioning and FEA strength analysis. The base load is deduced from forming technology theory. FEA is used to evaluate results of prior dimensioning and to evaluate proper design.

**KEYWORDS**

Steel bending; forming machine; design; strength analysis; FEA

## 1 INTRODUCTION

One of the main parts of the roof is the gutter system. Main function of gutter system is to catch the water from the roof and lead it to the ground. The gutter system consist of downspouts, gutters and gutter hooks. Gutter hook is an inseparable part of gutter system and his main goal is to hold the roof in stable position.

The main goal of this work is the construction of hand bender for gutter hooks. This device is very simple and hand controlled. The bender works on simple principle of bending around fixed disc. The bending process is realized by the hand controlled lever.

This thesis consist of three main parts. Research, technology design and my own construction solution.

### 1.1 Gutters hook

Gutter hook could be make from various types of materials. Standard gutter hooks are made of steel (S 235 JRGS), stainless steel (1.4301), aluminium or copper. PVC could be used for gutter hooks as well. [ČSN EN 1462]

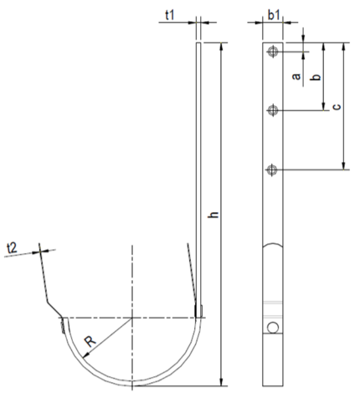


**Figure 1.** Gutters hook – general dimensions [Zambelli 2012]

Gutter hooks could be made from titanium-zinc – the material from the future. Titanium-zinc is basically combination of titanium and copper. These two elements are then mixed together with the zinc that added to the material strength and dimensional stability. One of the main upsides is long life and maintenance-free products. [Psenicka 2014]

**Table 1.** Mechanical properties of considered materials [Leinveber 2011]

| | Steel 1.4301 | Al 6061 | Steel S 235 JRGS |
|---|---|---|---|
| Re [MPa] | 210 | 110 | 186 |
| Rm [MPa] | 520 ÷ 720 → **600** | 205 | 330 ÷ 445 → **380** |
| E [MPa] | 210 000 | 70 000 | 210 000 |

### 1.2 Hand bender for gutters hooks

Hand controlled or fully automated machines are used for producing gutter hooks.

There are several sizes of the gutters with different dimensions. Hand bender is used to create gutter hook according to required dimension. There are two visible bends, see Fig. 2. For each bending on this picture is a bit different conception of manufacturing and little bit different use of the benders with different construction.

Bend 1 – bending technology - retractable

Bend 2 – bending technology – simple bending

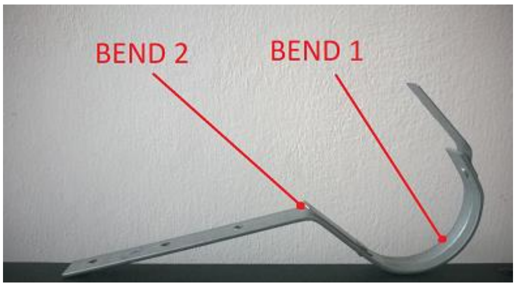


**Figure 2.** Two visible bends on the gutter hook

**Manufacturing process of bend 1 – constant bend according to required dimension**

Semi-finished product is inserted into disc of the bender (see Fig. 3). This semi-finished product is fixed in the disc once till it hits a stop. The semi-finished product piece of material is by being wounded around the disc with the assistance of lever and the pressing cylinder until it reaches the stop on the clamping part of the bender. There are several dimensions of the removable discs according to required diameter of the gutter hook.

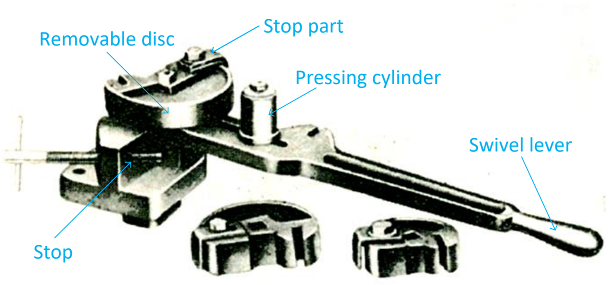


**Figure 3.** Hand bender for gutter hooks [Hysek 1971]

**Bend 2 – Variable bend according to drop of the gutter and according to the angle of the roof**

The main difference in this type of bend is with the semi-finished product. The semi-finished product in this type of bend is already deformed with bend 1. Band 2 is created with the bender with different construction.

**The bend 1 only will be considered at this work. The hand bender will be constructed for production gutter hooks with bend 1.**

## 2 DETERMINATION OF TECHNOLOGICAL FORCE

Calculation that is described in this list is for hook that is make from stainless steel 1.4301. The highest force values are expected for this hook because of the material with highest strength.

The main goal of this calculation is to find out the bending force and moment that are necessary to bend the semi-finished product material.

According to propriety legislation (z.361/2007Sb.) the maximum weight that could be lifted by a man *30 kg* and for a woman *15 kg*. I choose approximately half of the value for a man $F_{RAM} = 150\ N$. The $F_{RAM}$ force is placed at the end of a lever (beam). The length of a lever was designed to produce appropriate technology force.

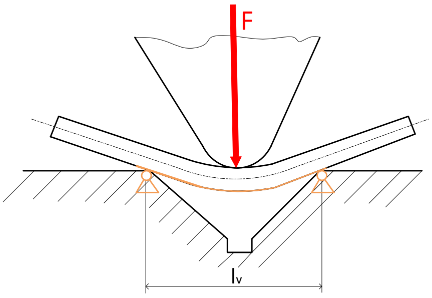


**Figure 4.** Bending process during bending with bending tool

A classic "V – shape" bending technology was used as an example within the construction process. This situation could be compared to a simple beam with two supports and one force in the middle of a beam. In case of hand bender is bending process compared to a beam with two supports and with overhanging end. It is known that beam with overhanging end and beam with two supports and double length and double load force are with the same load – this is the link between typical bending and considered case. The beam of hand loader is loaded with force $F_S$ (Force that is deduced by the pressing cylinder). And with the $F_{RAM}$ force that is an operating force. The $F_S$ force is split by the angle of 45° (chosen value) to the tensile part $F_R$ and to the shear part $F_O$. To hold whole system in a balance $R_{AX}$ and $R_{AY}$ reactions must be in a support. The reactions must be oriented in opposite direction to $F_S$ force. The arm of $F_S$ force on a beam is marked as $a$ and the arm of force $F_{RAM}$ on a beam is marked as $l$.

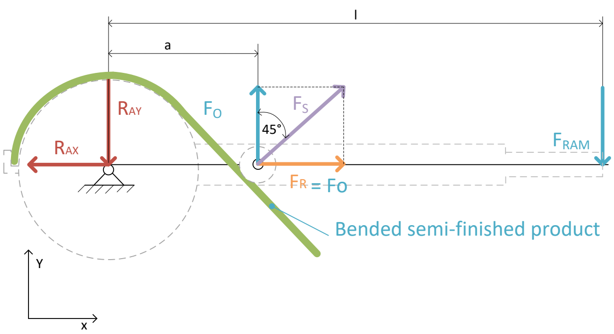


**Figure 5.** Two support beam loaded by forces $F_{RAM}$ and $F_S$

Reference [Lenfeld] to the bending moment calculation was used. At first the values of elastic relaxing have been necessary to identify. The elastic relaxing values tells to what diameter hooks must be bend. When the bending forces is ended the hook must be on required diameter.

For the selected $F_{RAM}$ force the minimum length of the arm marked as $l$ could be calculated.

### 2.1 *Example of define calculation*

Maximum stress during the hook bending:

$$\sigma_O = R_m \cdot C = 600 \cdot \left(1 + 4 * \frac{s}{l_v}\right) = 925\ MPa \quad (1)$$

$R_m$ ... Ultimate tensile strength

$C$ ... Strain hardening coefficient

$s$ ... The width of semi-finished product

$l_v$ ... The distance of supports

Moment of inertia:

$$J_X = \frac{1}{12} \cdot s \cdot t^3 = 450\ mm^4 \quad (2)$$

$t$ ... Thickness of semi-finished product

Necessary bending moment to make the bend:

$$M_O = \frac{\sigma_O \cdot J_X}{y} = 138\ 881\ Nmm \quad (3)$$

$y$ ... The perpendicular distance to the neutral axis

Reaction in a disc:

$$M_O = R_{AY} \cdot a \rightarrow R_{AY} = \frac{M_O}{a} = 869\ N \quad (4)$$

Length of a beam $l$:

$$M_O = F_{RAM} \cdot l \rightarrow l = \frac{M_O}{F_{RAM}} = 926\ mm \quad (5)$$

$F_{RAM}$ ... Operating force

$l$ ... The length of arm

**Table 2.** Results values for considered materials

| | Steel 1.4301 | Al 6061 | Steel S 235 JRGS |
|---|---|---|---|
| $M_o$ [Nmm] | 138 881 | 47 451 | 87 958 |
| $R_{AY}$ [N] | 869 | 297 | 550 |
| l [mm] | 926 | 316 | 586 |

## 3 CONSTRUCTION DESIGN OF BENDER

In the next part of article a concept of bender is introduced including the specific construction groups. Hand bender of gutter hooks is a simple device that consist of swivel lever, removable disc and a pressing cylinder. During the bending process the gutter hook is bended around the removable disc. The hand bender designed in this work should be very simple conception that is possible to fix or construct at a small workshop or at home. There are a few possible construction variants of a bender in our work from which we choose the most optimal variant that is mentioning here.

As the whole conception of a bender the variant with the "swivel lever" has been selected. It is the easiest systems of a hand bender that is based on winding the semi-finished product material (hook) around the removable disc. The bending process is started by the force that is at the end of the swivel lever.

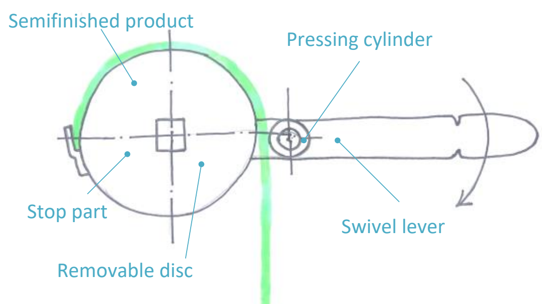


**Figure 6.** Final design – with lever

Construction of a pressing cylinder has been solved with the simple pin with a mount that is screwed through the lever. Above the mount a sliding bush is fitted to the decrease of a friction.

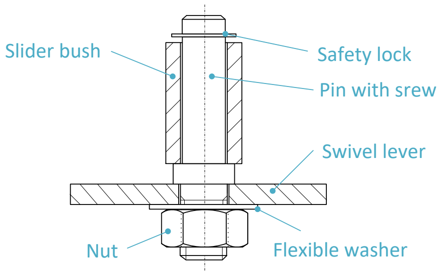


**Figure 7.** Pressing cylinder design

Four different positions of the pressing cylinder have been sold with four simple holes in the lever. When there is a need to move with the cylinder than the nut must loosen and the cylinder is simply placed into another hole and the nut is tightened again. The holes are in the distance referring to the radius of a specific disc and a thickness of bending material.

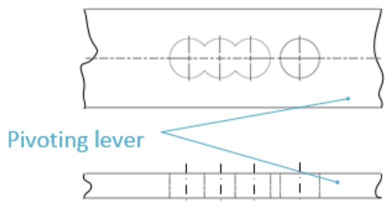


**Figure 8.** The holes for pressing cylinder in lever

The construction of the swivel lever has been innovated with the telescopic mechanism. Telescopic mechanism has been used because of different strength of materials of the hooks. The idea was to bend material with higher strength with the longer lever. The other (lover strength) materials could be bended with the shorter lever and compact dimension of the whole device. Default shape of the lever is standard flat bar. To this bar a round tube is welded. Principe of telescopic mechanism is to insert the tube of the smaller diameter to the welded tube. In the tubes two holes are drilled. The holes are spacedPin about some dimension and the position is fixed with a pin. To change the length of the lever the pin to be ejected inner tube is moved with and the new position of the pin is fixed again. The solution with the welded tube was used because of simple realization of the telescopic mechanism. Rounded shape is very ergonomic too.

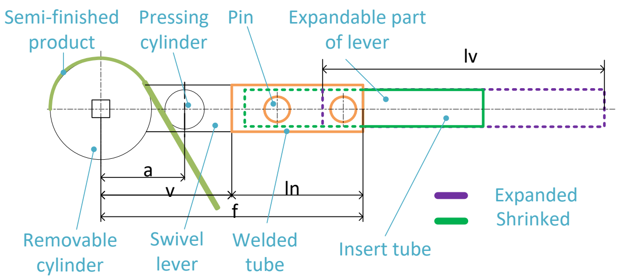


**Figure 9.** Telescopic mechanism of an swivel lever

### 3.1 Swivel lever dimensioning

The most loaded part of the hand bender of gutter hooks is the swivel lever. This chapter is focused on the dimensioning of the lever. Another very loaded part is the screw that connects cylinder to the swivel lever. The strength calculation of the screw is not described in this article. These two parts are loaded with the combination of loads. Calculation of each load is described and the final reduced load of the lever is computed here. From the reduced load the optimal dimension are computed. Dimensioning process is based on load that has been calculated for the hook from material Steel 1.4301.

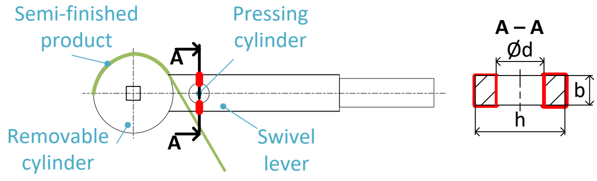


**Figure 10.** The critical place is in the lever

There is the combination of the loads in the lever during the bending process. (Bending moment $M_O$, tensile force $F_R$ and bending force $F_O$). Dimensioning of the lever is done in determined critical place. The critical place is in the area close to the drilled holes (see Figure 10). As the material of the lever the steel S355J0 has been chosen – flat bar 50 x 12 mm. The four holes of diameter 18 mm must be drilled into the bar.

Bending stress by the moment $M_O$:

$$\sigma_O = \frac{M_O}{\frac{1}{6 \cdot t}(t \cdot s^3 - t \cdot d^3)} = 57.3\ MPa \qquad (5)$$

$d$ ... The diameter of hole

Tensile stress by the force $F_R$:

$$\sigma_t = \frac{F_R}{S} = \frac{F_R}{t \cdot s - t \cdot d} = 4.654\ MPa \qquad (6)$$

$F_R$ ... Tensile force

Sheer stress by the force $F_O$:

$$\tau_S = \frac{F_O}{S} = \frac{F_O}{t \cdot s - t \cdot d} = 4.7\ MPa \qquad (7)$$

$F_S$ ... Shear force

Maximum allowed stress:

$$\sigma_D = \frac{R_e}{k} = \frac{333}{3} = 111\ MPa \qquad (8)$$

$k$ ... Safety coefficient

Reduced stress:

$$\sigma_{Red} = \sqrt{(\sigma_O + \sigma_t)^2 + 4 \cdot \tau_S{}^2} = 62{,}6\ MPa\ \leq \sigma_D \qquad (9)$$

From the calculation above it can be can be seen that the reduce load is smaller than the max. Allowed stress. That means that the dimensions of the lever passes.

### 3.2 Virtual simulation of load of the bender

Calculation is done for the longest lever that is possible to adjust with the telescopic mechanism. The hook type 400 from the material Steel 1.4301 was simulated.

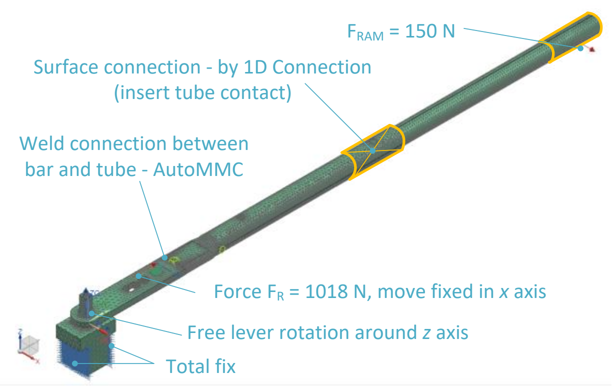


**Figure 11.** Virtual model

3D model used in the simulation consists of the clamping part, shaft for the disc and from the telescopic lever assembly. Welding connection is simulated with the command "Mesh Mating" (Mesh connection). The bender is fixed by the areas of the clamping part. Move of the pressing cylinder in the $x$ axis is disabled. Acting force the $F_R$ on pressing cylinder is situated 18 mm above the lever surface (see Fig. 11). Lever is free to rotate around $z$ axis in place of removable cylinder. Acting force $F_{RAM}$ that is at the end of the lever is situated to the on point. Model is meshed from the smallest elements. Fully meshed model is described at Figure 11.

Material of the lever stayed the same (Steel S355J0) with the yield point $R_e = 333\,MPa$. Selected values of maximum allowed stress are following: Max. allowed stress in lever $\sigma_{DP} = 200\,MPa$ and maximal allowed stress in weld $\sigma_{DS} = 180\,MPa$.

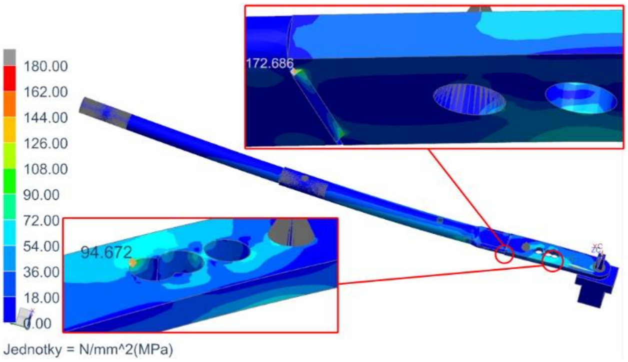


**Figure 12.** Maximum stress value

Maximum stress at the weld is $\sigma_{MAXS} = 172.7\,MPa$ and maximum value of stress in the lever was $\sigma_{MAXP} = 94.7\,MPa$. According to this results the conclusion is that the calculation of this variant passed. Both of the values are smaller than the value of maximal allowed stress values.

## 4 CONCLUSION

The main goal of this work was to design and construct innovated hand bender of gutter hooks. This tool is used in plumber's shop. Today's benders are not capable to bend gutter hooks from materials with higher strength.

In the introduction of this contribution detailed research was performed. The research was focused to bending technology and the mostly used dimensions and materials of gutter hooks. The calculation of bending moments and bending forces was performed for chosen angle between semi-finished product and bender lever (45°). Then minimal length of a bender lever has been calculated. Contribution also describe different construction variants of hand bender including selection of the most optimal variant.

In the next part of contribution the dimensioning of the selected parts and strength analysis has been done. The optimal construction variant of bender has been innovated during the thesis. The innovation was the telescopic lever that make bending process easier for hooks made from materials with higher strength.

Autodesk inventor and Siemens NX has been used to create 3D model of the hand bender. MKP analysis has been done with the Siemens NX. The analysis includes simulation of working loads and the specifications of the most loaded areas. Construction documentation for the whole bender has been created with the Autodesk Inventor.

This contribution represents design approach with technology entry. Bending technology was described and used as boundary conditions for strength analysis.

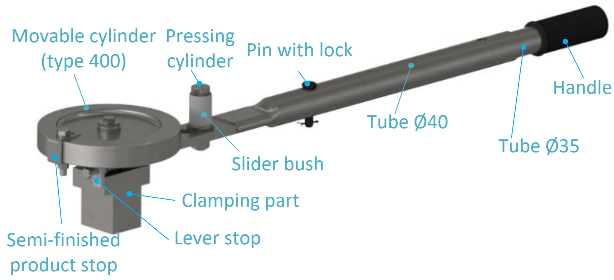


**Figure 13.** Final detail view of hand bender

Fig. 13 – Final detail view of hand bender proves that the task at the beginning of the work has been completed. This contribution also could be used as the instruction for design and construct a simple device such as this hand bender.


## ACKNOWLEDGMENTS

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## REFERENCES


**[CSN EN 1462]** CSN EN 1462 - Brackets for eaves gutters - Requirements and testing. Praha: UNMZ, 2005.

**[Hysek 1971]** Hysek, R. Forming machines. Praha I: SNTL – National publishing house of technical literature, 1971.

**[Leinveber 2011]** Leinveber, P. V. J. Engineering tables. Praha: Albra, 2011.

**[Lenfeld]** Lenfeld, P. Technology II, TU Liberec [online]. [10/2015]. Available from < http://www.ksp.tul.cz/cz/kpt/obsah/vyuka/skripta_tkp/sekce/07.htm>.

**[Psenicka 2014]** Pcenicka, M. Plumbing Psenicka. Vrchotovy Janovice [online]. 2014 [10/2015]. Available from < http://www.kpmetal.cz/titanzinek.php>.

**[Zambelli 2012]** Zambelli. Rinnenhaken „Modell Österreich“. Zambelli Fertigungs GmbH & Co. KG, 2012, Grafenau/Haus im Wald, Germany [online]. 2012 [04/2016]. Available from < http://www.zambelli.cz/fileadmin/_migrated/content_uploads/Rinnenhaken_Modell_OEsterreich_10.pdf>.


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