Mechanizing parts of a TIG hot wire welding process

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Preface

Our thesis is written as a part of the course MAS150 Bachelor Thesis – Mechanical Engineering. This is the accumulated result of three years at Western Norway University of Applied Science. Our supervisor from the department of mechanical engineering is Saeed Bikaas. The project is from an extern company in the mechanical industry, BRIAS AS. Thomas Holbye is the welding coordinator in the company and have been our contact person during the project.

The project is financed by BRIAS. We want to thank them, especially Thomas, for giving us the necessary follow-up and enough leeway to solve this project ourselves. We also want to thank Alf Berland for facilitating the workshop for our needs.

We want to thank HVL lab engineer Bernt Hustad Hembre for crucial contribution regarding the electrical components in our project.

Summary

This thesis describes the design process of a TIG welding rig for the company BRIAS. The objective was to make a partly mechanized welding rig to simplify their TIG-hotwire welding process for pipes. The task was to design the rig and for the company to be able to build the rig, to use it in their daily work. The mechanical engineering skills were put through a test with 3D-modelling, design, project management and practical thinking.

The process begun with making a requirement list together with the company. Further on we started coming up with ideas and sketching them by hand. The best ideas were brought into Creo Parametric to be 3D-modelled. A lot of ideas where changed and new ones where found along the way. When the final models where finished, drawings were made and sent to the company so that they could make the rig.

Overall a satisfying result. The company has received the drawings so that they could make the rig and use it as they wish. It was a challenging task that tested the group widely in the mechanical engineering trade.

Samandrag

Denne rapporten går gjennom designprosessen av ein TIG-sveiserigg for bedrifta BRIAS. Problemstillinga er å konstruere ein delmekanisert sveiserigg som skal forenkle ein TIG-hotwire sveiseprosess på rør. Oppgåva vår er å designe riggen og målet for bedrifta er å kunne byggje ein modell for bruk. Her vart vore evner som maskiningeniørar testa innan 3D-modellering, design, prosjektering og praktisk tenking.

Prosessen byrja med å lage ei krav- og ynskjeliste saman med bedrifta. Videre føretok me ei idémyldring og byrja å skissere for hand. Dei beste ideane vart tekne vidare inn i Creo Parametric, kor dei vart modellert i 3D. Mange idéar vart endra og nye idéar kom opp undervegs i prosessen. Då modellane var klare vart det laga arbeidsteikningar slik at bedrifta kunne produsere dei.

Alt i alt vart det eit tilfredsstillande resultat. Bedrifta har fått teikningane og skal byggje riggen for eige bruk. Det vart ei utfordrande oppgåve som testa gruppa bredt i designprosessar og nytenking.

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1 Introduction

The thesis is based on design, engineering and prototyping. We wanted to combine designing and practical work of building a prototype. BRIAS AS had a perfect task for us to solve, allowing us to get both the theoretical and the practical side of a project.

BRIAS is a company specializing in high-alloy steels. They perform welding, sheet metal work, piping, cutting / machining, mounting & installation on / offshore.
Design / drawing and strength calculation is performed internally and externally [1] .

1.1 Motivation

This project is to design a welding-rig that makes welding easier for the operator. We are doing this project for BRIAS (Bergen Rustfri Industri AS). This is a company specializing in work on and welding stainless steel materials.

The thesis is regarding to the company's TIG welding process with preheated filler material. This process is highly demanding when it comes to the skills of the operator. Mainly due to the filler material being preheated, thus requiring little to none of the arc heat to melt into the weld, making this welding process very fast. The operator must do everything in the already demanding TIG welding process faster. The result is varying due to the level of difficulty in the process. At the end of this project, this process is made easier and more consistent with the help of this welding rig.

Our objective is to develop a welding rig for BRIAS. We are going to develop a rig which simplifies the welding process by removing the need for hand welding. The rig has a primary focus on welding pipes by rotating the workpiece and welding with an adjustable position welding gun. There are already solutions to this problem available on the market, but we will make a rig more dedicated to only this company and their needs.

1.2 Objective

The objective of our project is to develop a welding rig for BRIAS. Its main goal is to make the welding process of pipes easier and to improve the quality of the weld. Our solution will remove the need for hand welding which will make the operation more consistent.

This task contains sub objectives:

- *Designing a framework for the rig*: Finding a solution for a solid frame, guideways, chuck placement and support for the workpiece while operating.

- *Positioning*: Finding a solution for positioning the welding gun both rough and precise along the workpiece.

- *Designing a pendulum movement:* Designing a movement mechanism so that the welding gun can move back and forth filling a wide welding groove.

- *Designing a spring and roller system:* Finding a solution for maintain a constant distance to the workpiece while welding.

- *Operation controllers*: Add electrical or mechanical controllers for the operator to use.

1.3 Requirement list

Table 1. Requirement list

D/W	Requirement	Responsible
	1. Geometry	**All**
D	Movement in longitude direction: up to 2 [m] ±10mm	
D	Diameter range: 25 – 400 [mm]	
D	Operating controllers and cranks 1 meter above ground	
D	Clearance of 500 [mm] radius from center	
	2. Guideways	**Joachim**
D	Able to support the weight of carriage	
D	Ability to adjust position both roughly and precise	
	3. Table	**Eivind**
W	Minimize distance between chuck and gearbox	
D	Fasten to floor	
D	Grounding clamp attachment point	
	4. Support	**Eivind**
D	One support fixed along center position/line	
W	Space for additional free supports along centerline	
	5. Welding gun base tower	**Nikolai**
W	Button for starting motor and welding	
D	Ability to rotate ±90° around vertical axis	
D	Be rigid enough to not move from roller displacement	
W	Dedicated holder for controller to motor, sideways movement of gun and start/stop welding	
	6. Welding gun arm	**Nikolai**
D	Automatic zigzag motion during welding	
D/W	Spring system for proximity adjustment during welding. 2-3mm optimal distance from weld	
	7. Material	**Joachim**
D	Non-flammable	
W	Use material from stock	
D	The material must be able to carry the load	
D	Electric conducting material for grounding	
	8. Safety	**All**
D	Cover on rotating shaft	
W	Cover for welding light	
	9. General	**All**
W	Boom for cables from welding machine to base tower	
D	Easier to use the rig for welding than doing it manually	
W	Replace chuck with a new self-centering one	
W	Make it low cost, but still quality build	
W	Once a month maintenance	
D	Operating temperature 10-30°C	
D	Able to transport rig around workshop (lifting)	

2 Literature Review

2.1 Welding

Welding is a method of joining two elements permanently by using heat. The process heats up the parts melting them together with or without using a filler to fill in the gap between the parts. The most common materials for welding are metals and thermoplastics.

In welding, as opposed to soldering and brazing, the base or parent metal is melted in the process. Depending on which type of welding you do, you may or may not need filler material, though most welds require it.

The most common types of welding are TIG, MIG/MAG, MMA, cored wire and gas welding. All of those under the category of fusion welding. Each of those has their own characteristic technique and application. In this project, the focus will be on TIG welding.

All the mentioned types of welding except for gas, runs on electricity. A high current is needed to create a welding arc. The arc can reach temperatures up to 18.000 degrees Celsius in TIG welding [2]. The extreme heat is more than enough to melt the workpiece and create a welding pool where the materials from the different workpieces melts together. The filler material added usually has the same material composition as the workpieces being welded, but in some cases, it will have a different composition.

One type of widely used welds is the fillet weld. Fillet welds are when one welds together two pieces in an angle. In Figure 1, a standard 90 degrees fillet weld is shown.

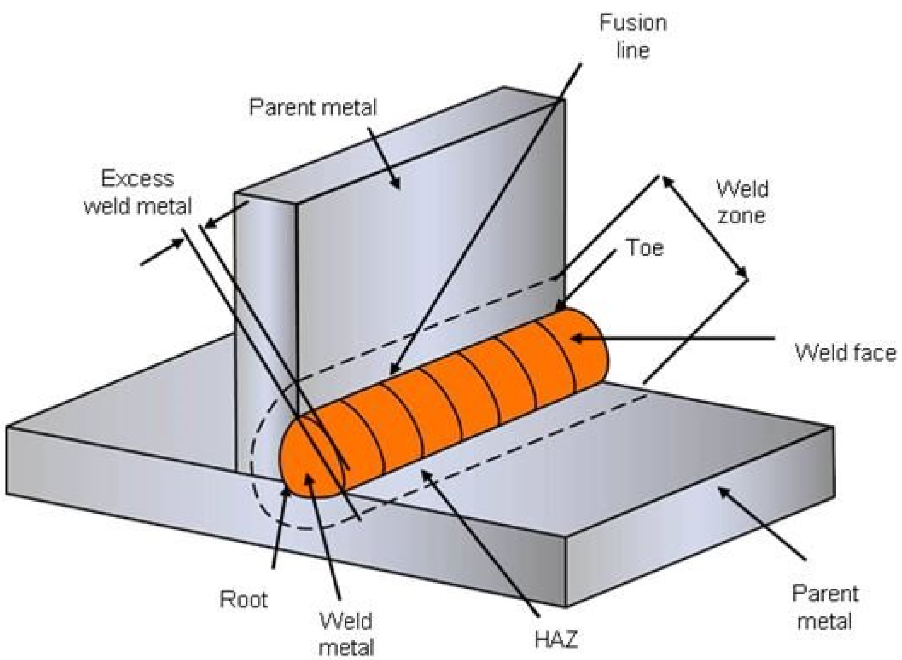
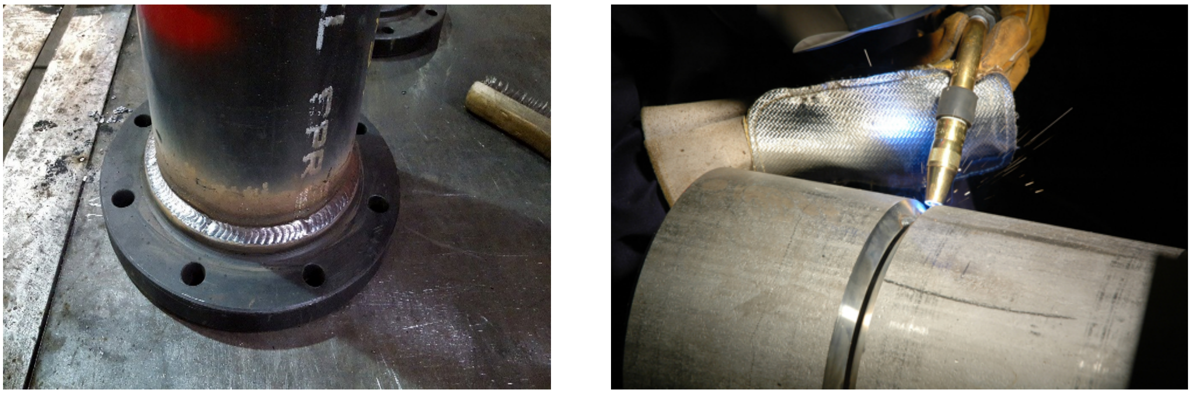


Figure 1. Fillet weld schematic [3]

Another popular weld is the pipe welding. This is the one our project is about. It can be welding a flange to a pipe as shown in Figure 2-a or welding two separate pipes together as illustrated in Figure 2-b as well as some other cases.



a) ***b)***

Figure 2. a) Welding flange to pipe [4]   b) welding two pipes together [5]

2.2 Equipment

To be able to weld, there are some essential equipment needed. Here we will focus on the equipment needed for TIG welding.

First, we need a welding machine (Figure 3F). This must be connected to a power outlet suited for high voltage. This machine supplies the correct voltage and current needed, based on how you configure it. The machine being used for our project is a “Tetrix 451 AC/DC Comfort 2.0 pulse”. This machine supplies up to 450 amperes and is water-cooled to prevent overheating [6]. Connected to this you have a cable which leads to the welding gun (Figure 3-element D). This is what the operator holds while welding. There is a foot pedal (Figure 3-element B) to start and stop the welding. Some guns have buttons for this on the gun itself.

To start welding there needs to be a closed electric loop, meaning that the electricity you put into the workpiece needs to have a way to get back to the welding machine. This is done by connecting a grounding cable (Figure 3-element E) to the workpiece or a metal surface in direct contact with the workpiece.

Furthermore, shielding gas (Figure 3-element A) and the tungsten electrode (Figure 3-element C) are two necessary pieces of equipment for TIG welding. An elaboration on these two can be found in chapter 2.4.

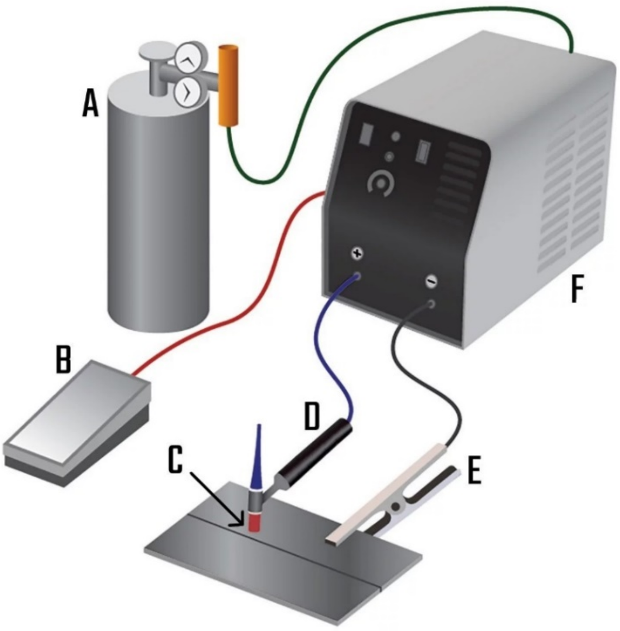


Figure 3. TIG setup [7]

2.3 Safety

Before welding there are some safety precautions to take. All the basic workshop PPE (Personal Protective Equipment) needs to be in place [8]. Here are some explanations on the welding specific PPE.

Most important is the welding mask. The mask protects your eyes from the intense and dangerous light from the welding arc. The strong UV light will if stared at directly, burn your retinas, resulting in something called welder's flash. This causes temporary blindness and extreme discomfort. To prevent this and still be able to work the modern welding masks has automatically dimming of the light through the mask. When you are not welding the glass will be like a regular glass, but when you start welding the glass will restrict the amount of light going through. The same UV light will burn your skin if not covered up. The skin will get burnt much like getting sunburnt. Therefore, you need to cover all naked skin with a proper material, like a boiler suit. The suit also needs to be flame retardant, to prevent it catching on fire if sparks hit it.Gloves made for welding is very good for protecting against heat. If you touch something very hot while wearing those, you will feel the heat and be able to take them off before your fingers get hurt. Safety boots is required in most places where welding takes place.While welding it may be necessary to use an exhaust fan to remove the harmful emissions coming from the weld and/or the gas you are using. If you do not have that, you can use a respirator mask with a filter on. In Figure 4 the equipment mentioned is shown.

Figure 4. Safety equipment [9]

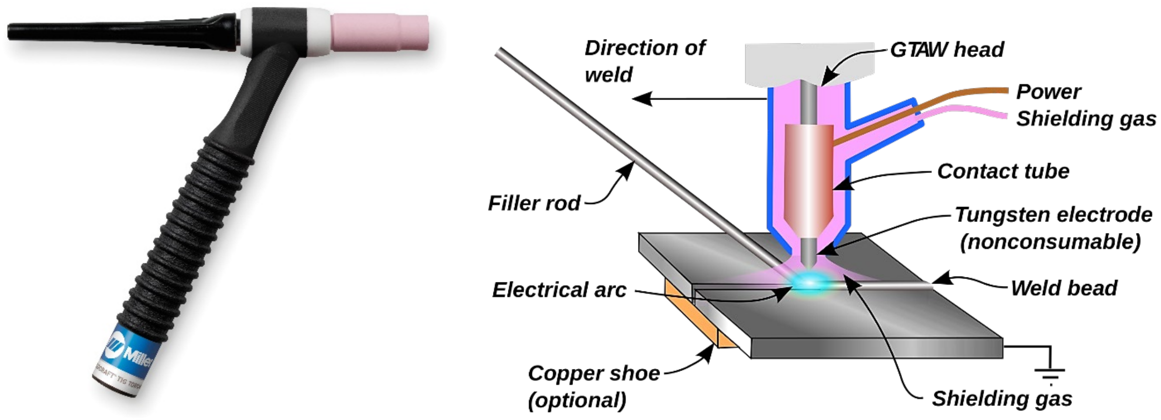
2.4 TIG

TIG welding which stands for Tungsten Inert Gas welding, is a welding method which uses a tungsten electrode and most commonly argon gas as a shielding gas. In normal TIG welding, it may or may not be a need for filler material in the welding process. If needed, the filler material will be in the shape of a thin rod, being fed into the welding pool by hand. A TIG welding gun is shown in Figure 5a.

TIG is considered a difficult welding method, but also a very precise one. The finished weld is without any slag and rarely needs any more work after. The reasons it is difficult is due to the facts that it requires the welder to do two different operations at the same time. One hand is feeding the filler material at a steady rate, the other is moving the gun in a zigzag movement across the weld. This movement is important to evenly distribute the heat over the groove and get the weld deep into the material on both workpieces. The electrode must be kept roughly the same distance away from the pool as the diameter of the electrode. The electrodes vary in size from 0,5 to 6,4 mm diameter [10].

Tungsten has a melting temperature of 3422°C [11] and will not be consumed during the welding process. This allows the electrode to be used repeatedly. However, the electrode might be slightly damaged in the process, then it needs to be grinded to regain the same properties as it had. The electrodes angle and finish at the tip decides how much heat it can produce. Different angles and finishes have different uses, so the electrodes will be altered or swapped out for what is needed for the specific weld.

The shielding gas is important in TIG welding. The most common shielding gas used for TIG welding is argon [12]. The gas shields the weld from other gases like nitrogen and oxygen. These other gases can cause defects in the weld and make it porous, something the weld should not be. The gas also helps the arc transfer heat into the weld, keeping the weld stable. In Figure 5b you can see how shielding gas, shown in pink color, is shielding the arc and pool. It is also a good representation of how the setup and process of welding two plates together is.



a) *b)*

Figure 5. a) TIG welding gun [13] b) TIG welding process schematic [14]

2.5 TIG Hot wire

TIG Hot wire is a special case of TIG welding. The difference being automated wire feeding, and as the name implies, the wire is hot. This separate machine sits on top of the power supply. Inside is has a spool feeding filler material to the welding gun. Before entering the weld, the filler is heated. From the wire feeder the wire is fed through the same cable as all the other wires to the gun. The wire feeding removes the need for a manual feed with the second hand. With this the welder could use both hands on the gun, keeping it more stable and getting a better weld. The buttons on the gun as seen in Figure 6 controls the feed rate and start/stop of welding. If Figure 6 and Figure 5-a is compared, you can see the main difference being the white and the black cable. The white one is where the wire is coming through, and the black one is power cable going to the heating element. The wire is heated going through, being close to melting when coming out. Because the wire is already hot when it comes out, that means almost all the arc heat can be put into the weld. Not needing to heat the wire makes the welding go much faster than regular TIG welding. Up to 100% faster according to the manufacturers [15]. It is also possible to get this in a cold wire setup. The difference is as the name suggest, the wire is not heated.

When it comes to welding on pipes, like our project focuses on, the position on the pipe matters. In Figure 17 you can see the quadrant our rig is going to weld in. The upper 90 degrees of the pipe. The main position, where most pipes will get welded is a bit over the center line. This is because when you weld, the pool will flow a bit downwards. By welding there and having the pipe turning towards the gun (welding up) the pool will be able to settle on itself. This makes it possible to fill even more filler material into the weld, creating a good and thick weld. Welding on top of the pipe will only be done in special cases where the operator sees it fit.

Figure 6. TIG Hot wire gun [16]

2.6 Similar products for the mechanism on the market

There are several products on the market that serves the same purpose as our welding rig. Here we will list and explain short some of the products. Keeping in mind that all of these are in the upper price range compared to ours. This is mainly due to being made by a big company and with a bigger team of engineers to working to perfect it.

2.6.1 K-TIG

K-TIG is one of the high-end products within the same product range as our TIG hot wire rig. They offer customized welding rigs and use even faster TIG welding than hot wire. Up to 100x times faster than regular TIG [17]. They are an Australian company delivering rigs to costumers globally.

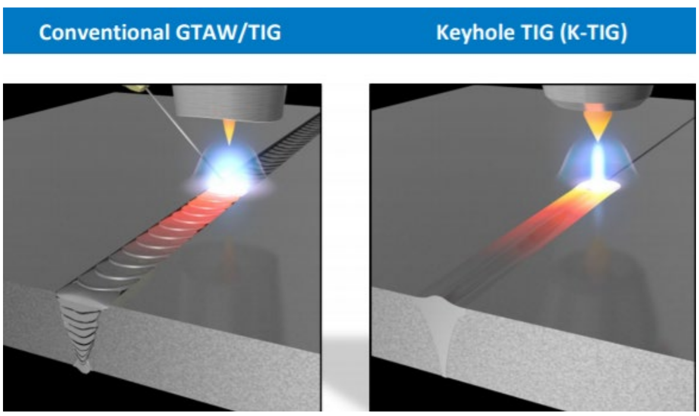


Figure 7. Conventional TIG vs K-TIG [17]

2.6.2 Collaborative robot

Novarc technologies has a collaborative robot with three degrees of freedom. This allows for rough adjustments of the entire robot arm for placement, and precise adjustments along together with the robot during the welding process [18].

Figure 8. Novarc collaborative welding robot [18]

2.6.3 Robotic pipe welding

Different types of fully automated welding robots are already being used worldwide. Car manufacturers like Mercedes are using them for all welding car chassis. The prices vary based on precision needed, power and size.

Figure 9. Fully automated welding robot [19]

2.6.4 Automated welder

With the guide mounted as a sleeve, this machine moves around the pipe while welding. It comes in several different configurations. Pipe range is above Ø100mm sizes [20].

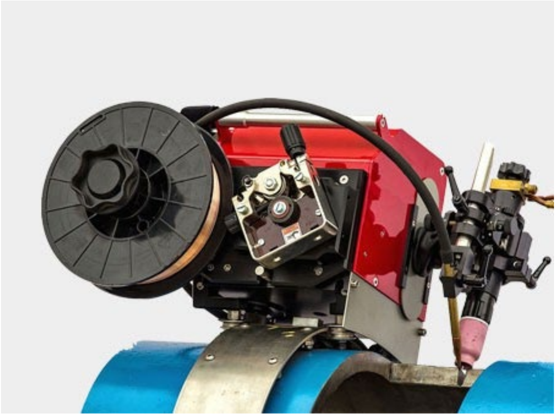


Figure 10. TIG automated welding system [20]

3 Development

Building a functional welding rig from scratch relies on choosing the right design and engineering solutions from the start. We must consider every option and compare the strengths and flaws against other design choices. Our design is based on the requirement list from the costumer, trying to satisfy the costumers needs and wishes. Selecting the right materials and building in known industry standards. Also taking into consideration that some wishes might not make it to the final design for reasons that can have a negative effect on the overall function of the rig.

We split the rig into the following parts.

- Framework for the rig
- Support for the workpiece while welding
- Guideway for the welding arm
- Mechanism for adjusting the position of the welding gun

3.1 Framework for the rig

The current setup the company uses has no binding framework. This is a table (as shown in Figure 11) and a standalone support rest. The company asked us to build a rigid construction with all the different components mounted together. The table used serves its purpose however it is far from effective use of space. If we look at the table as a part of the rig, we see that there is no need for any new engineering ideas, only improvements. With an unnecessary long axle form the motor to the chuck and bulky design it is easy to see what is needed for an improved design. We suggest the following:

- Shorten the axel length
- Down scaling the table size
- Making a clean and slimmer framework.

Figure 11. Table used by the company

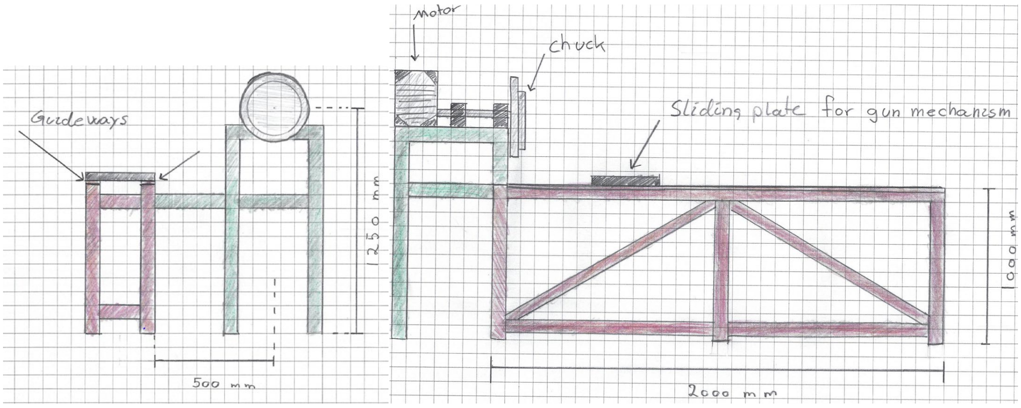


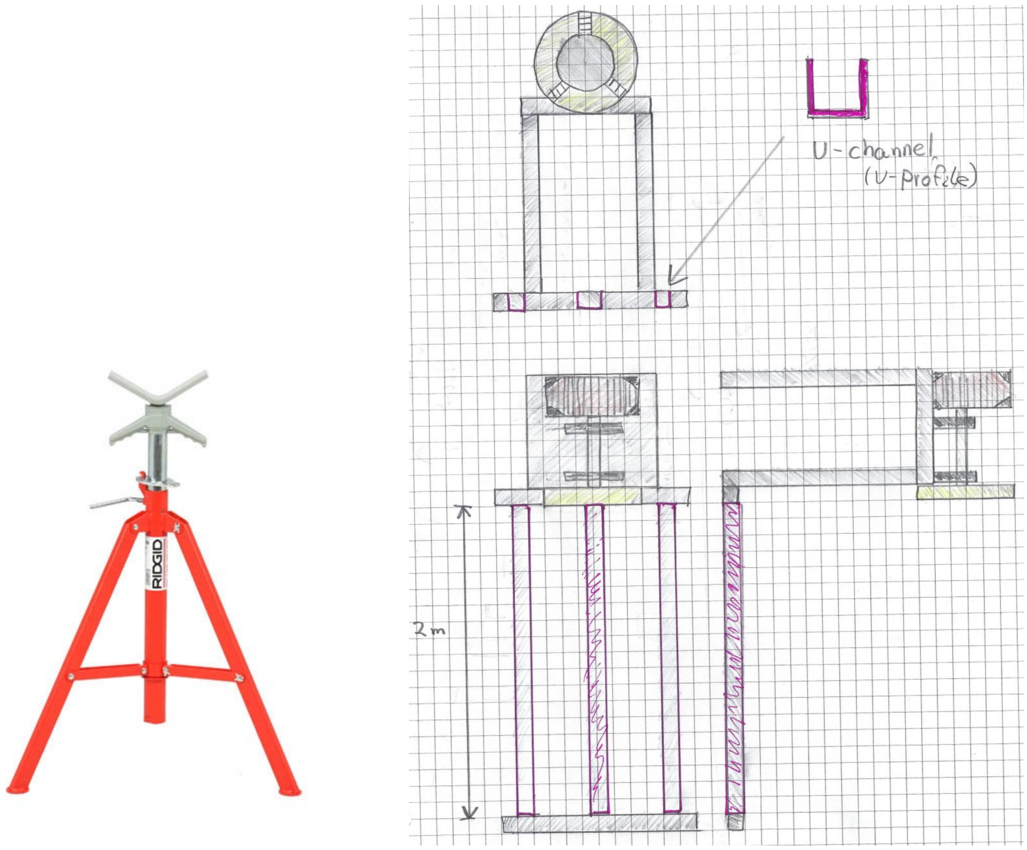
Figure 12. sketch for framework of table and guideways.

Figure 12 shows a sketch of the table and guideways mounted together. These two sections will be connected to a third section, the channels for the support rest shown in Figure 13. The green part in Figure 12 represents the new design for the table and the red part is the guideway section. There would be mounting brackets on every leg for floor mounting, but the different sections could also be removed individually for easy transport. On the guideway section we have taken a few measures to ensure that there would not be any deflection, and to ensure a smooth sliding motion for the gun mechanism. The current table had a counter weight to stabilize it when welding bigger pipes, but we feel that with the legs mounted to the floor and the support channels on the floor that there would not be a need for us to design a new weight.

As far as the measurements go, the only fixed measurements are the distance form center of the chuck to the nearest part of the guideway section and the total length of the guideways. The distance from the center of the chuck to the guideways must be 0,5 m radius for the rig to handle pipes with projecting parts on it. In addition, the total length of 2 m is to fulfill the demand in our pipe size range. Other than that, we could work quite freely and decide what would be appropriate heights and widths. Having the work height at the gun mechanism to be around 1m and the chuck to be placed slightly higher for good visibility while working.

3.2 Support

Designing the support for the workpieces is similar to what we did on the 3.1 table, they already have a support that they use in their current setup. The existing welding rig used by the company has a separate tripod rest that we can modify by putting wheels on it and placing it in channels.



a) ***b)***

Figure 13. a) Tripod support rest [21] ***b) Base layout for support U-channels***

The company requested that the support would be connected to the construction, rather than being free to move like they had. As an extra addition to the support we thought of having a tailstock at the back end of the workpiece, but this was deemed not necessary. The operator values the easy mounting and removal with just a support under the pipe, and the spring and roller system would counter work potential uneven pipes and improper mountings of pipes. Figure 13-b shows the base layout for the channels which the support could move in, the only adjustment options for the support rest is height adjustment and travel along Z-axis. The channels will be mounted at the bottom of the table right under the chuck, with center of the chuck and the support being aligned. Having the channels on the floor will also have a strengthening effect on the whole construction. And with the channels in place there is no problem placing another support rest in the channels if there ever should be the need for that.

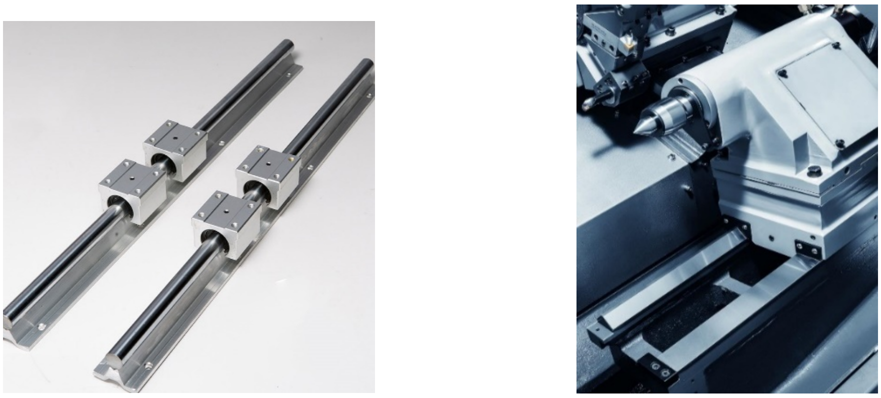
3.3 Guideway

The purpose of the guideway is to transport the welding gun along the pipe or Z-axis. From the requirement list the guideway must be able to cope with the load placed upon it, further on it must be able to be adjusted both roughly by hand and adjusted precise with a turning wheel. This is for making the welding procedure easier for the operator. The total length of the guideways must meet the requirement of a length of 2 meters.

To generate ideas, we had a look at different lathe machines to see how they designed guideway. We settled on having two guideways parallel to each other, one guideway would be leading and the other to be freely sliding.

We thought of having the carriage which slides on the guideways to be gear driven for adjustment. However, in meetings with the company and having the operator in mind we thought of making this part more user-friendly. Instead of it to be gear driven we came up with the idea to have the carriage slide freely on the ways and only to by placed roughly in the right position, then fasten with a screw or locking mechanism. This makes for much quicker adjustment and simplifies the design. The operator needs to have the option for precise adjustment so we figured out that it would be a smarter to places this option on top of the carriage, more on that in paragraph 3.4.2

Our guideways do not have to be build heavy-duty manner like on lathe machines, because there is only the weight of the gun mechanism that is producing the load and there are no vibrations. After figuring out the base layout of the guideways, we verify the availability and manufacturing guideways.



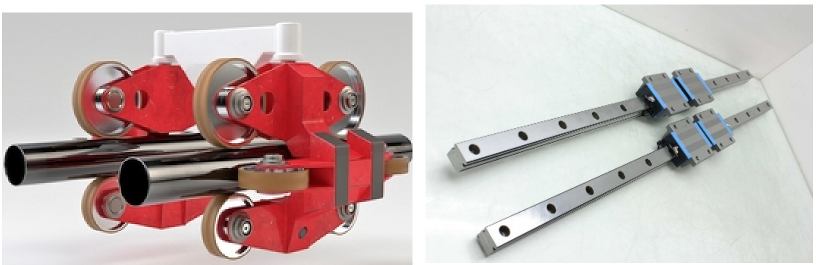
(a) ***(b)***

Figure 14. a) Cylindrical ways [22] b) Lathe ways [23]

On a 2-meter-long guideway, there is difficulties we need to find a solution for. With this distance it is crucial that the guideways are made perfectly levelled and straight, to avoid jamming. And by having one guideway leading we also lower the risk of jamming.

Our ideas for guideways are:

- Cylindrical guideways (Figure 14-*a)*
- Lathe ways (Figure 14-*b)*
- Clamping mechanism from roller coasters (Figure 15-a)
- Rails (Figure 15-*b)*



(a) ***(b)***

Figure 15. a) Clamping mechanism from roller coasters [24] b) Rails [25]

With these ideas we extract their perks and combine them to make the perfect guideways for our rig.

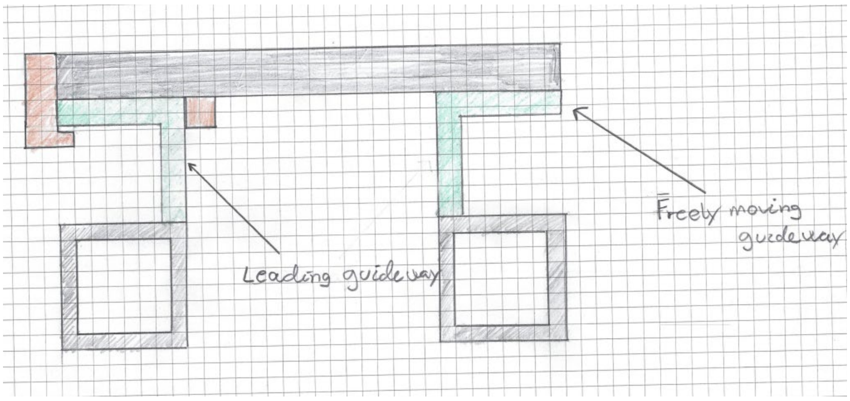


Figure 16. Sketch of guideways seen from the side.

Figure 16 shows a sketch where two angled bars are mounted on top of square pipes, with one leading guideway and one freely moving. This setup has minimal chance of jamming and fulfils the strength requirements with no deflection. It is also very easy to manufacture and assemble. To optimize this design, we can make small grooves in longitudinal direction on sliding plate where the plate meets the angle bar, to lower the friction.

3.4 Gun mechanism

The positioning for the welding gun is one of the most important part of our welding rig. Its purpose is to adjust the welding angle on the pipe and the distance in every direction. Our goal is to make a mechanism that fit the given criteria and would be easy to operate. For this rig to be operational and usable in a workshop it must achieve close if not similar results as hand welding, hopefully better. For accurate and consistent welding, the welding gun must keep a fixed distance of 2-3 mm for the workpiece under the whole welding process. For this problem, we thought of some spring and roller system for maintaining this distance. However, for our rig to replicate hand welding the mechanism must not only be able to adjust angle and distance but mimic the pendulum technique welders do when TIG-welding. We have split this mechanism into sub parts:

- The “tower” which adjusts the position on the Y axis, the height adjustment.
- The “arm” which adjusts position along X and Z axis, or in other words towards and along the workpieces
- The “pendulum”, for filling welding grooves in a similar way of hand welding
- The “spring and roller” system, for maintaining a constant distance to the workpieces while welding.

3.4.1 The Tower

The tower as we have named it is the height adjustment for the welding gun. The welding gun needs to travel for 90 ° straight into the pipe to top of the pipe as shown in Figure 17. The red area symbolizes the zone where it is required for our rig to be able to weld. And with a maximum diameter of 400 mm, its necessary with a travel of a minimum of 200 mm to handle every pipe diameter in our size range. However, taking account for the option to adjust the angle and position on the welding gun we figured out that the total travel had to be extended to 500 mm.

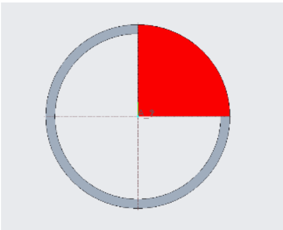
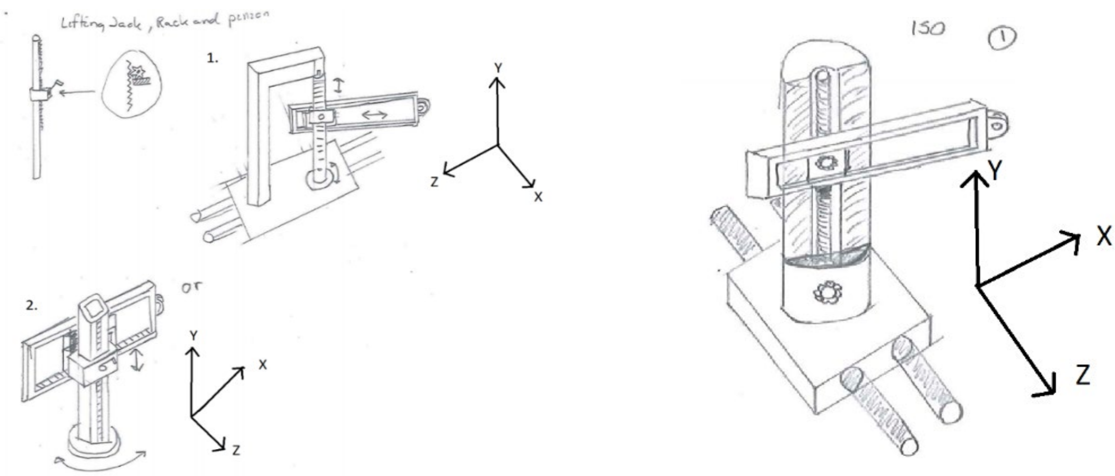


Figure 17. Welding zone

You can find inspiration for this problem by looking at different lifting equipment. Our goal is to have a simple yet very functional design, so a lot of lifting equipment is quite over dimension for our rig but a similarity between them is that they use a pinion and rack system. This system fits our tower perfectly because of the self-locking which occur if a worm gear drives the pinion.



a) ***b)***

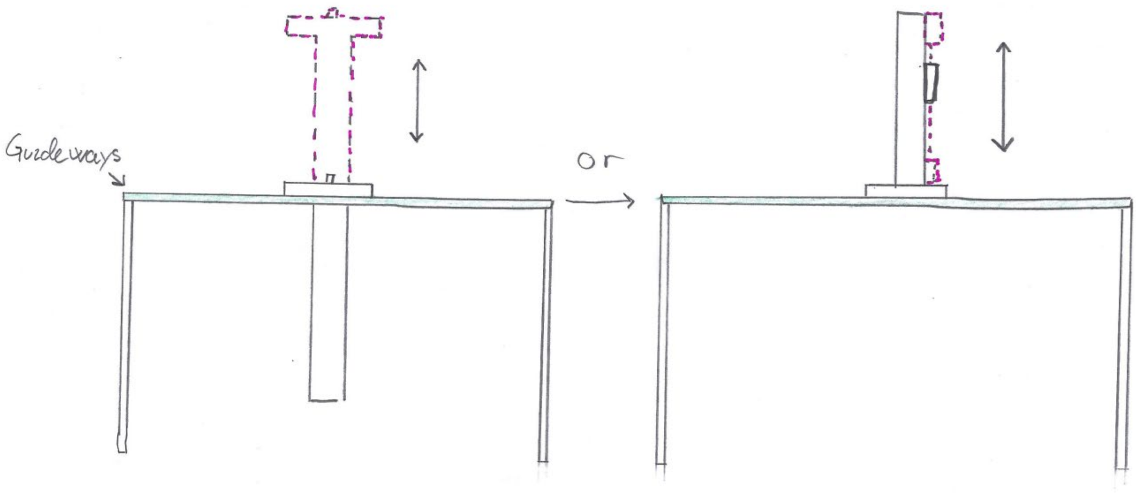
Figure 18. a) Two tower design using pinion and rack. b) Tower design using a trapezoidal screw.

As shown in figures above you see our very first ideas on the tower, all with a different twist on the pinion and rack system. Our thoughts were that we either buy the different gears and build the housing our self or modify a jack to fit our design. These designs are driven by a hand wheels to adjust the height. Further on we thought of the option to making this part electrically driven, this was to avoid possible challenges that may occur when constructing a gear housing. With an electrical approach the operator would only need two buttons to adjust the height.

a) ***b)***

Figure 19. a) Rack and pinion jack [26]   b) Electrical linear actuator [27]

And back to our goal to make a simple yet functional design, we thought of having the tower built in between the guideways instead of it sitting on top. This idea came from the thoughts of giving the operator a clear line of sighted when welding. We also debated on whether to have to rotation on top of the tower or rotate the tower itself, depending on whether the tower was built in between the guideways or on top.



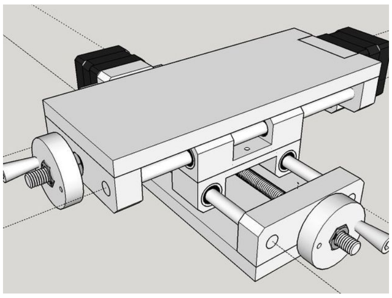
a) ***b)***

Figure 20. a) Dynamic tower underneath ways. b) static tower above ways.

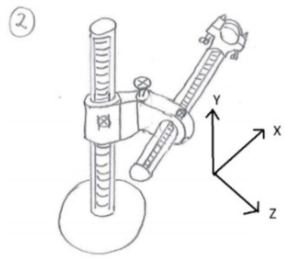
As for the summary of our setup form the tower, we feel that the dynamic tower built in between the ways would be the best design for our rig. It gives a clear line if sight and would not cause any obstructions for the operator. And it should be driven by the electrically driven actuator, because of the unnecessary complications that might occur when building a gear house or modifying a lifting jack.

3.4.2 The arm

The arm is very similar to the sliders found on lathes machines, its purpose is to position the tool along the workpiece, with the possibility for adjustment in X and Z direction. The main differences from lathe machines are that our arm needs more flexibility to handle different welding situations. Regardless of whether we choose a tower built in between the guideways or resting on top of them, the arm needs to be able to adjust the distance from the guideways to workpiece and rotate ± 90 °. The mechanism for moving the arm back and forth could either be a trapezoidal threaded screw moving a nut or a pinion and rack solution. Looking at different slider it its most common to find the screw solution. Originally, we thought of having the whole carriage to be gear driven along the guideways but decided to have a slider at the bottom of the arm for adjustment in the Z axis, as shown in Figure 21 a. (Figure 18 also show ideas for *arms).*



a)



b)

Figure 21. a) Compound table with Z and X axis adjustments [28] b) Sketch of arm

Figure 22. Arm using pinion and rack. [29]

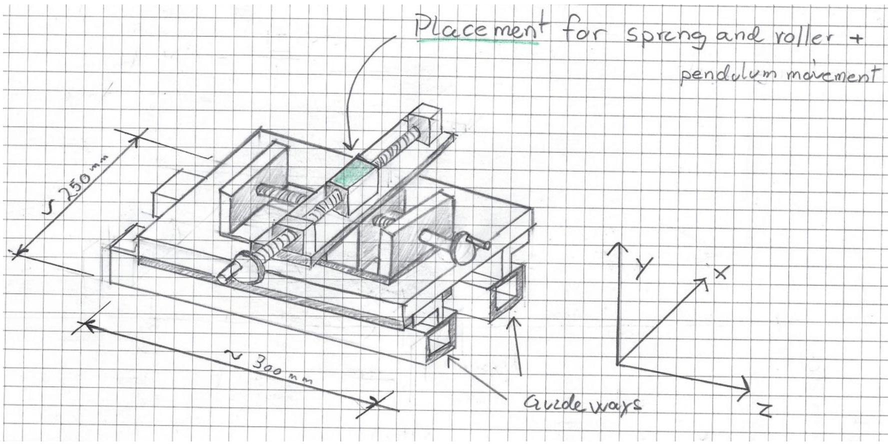


Figure 23. Sketch of x-z sliders

Therefore, Figure 23 took inspiration from different kinds of sliders found in workshops. This sketch has not included the *tower* option, but it would either be places on top of a dynamic tower or adapted to a static tower. There is no need for heavy-duty equipment, our only demand for our slider is that it must be adjustably accurate down to millimeter level. The team wants the operator to have a good feel when adjusting while welding, therefore we want the arm to be adjusted with manual hand wheels instead of electric buttons. To summarize on the arm, we feel that manual handwheel sliders would suit our rig. It is fairly common to use these types of slider in equipment like our rig and its highly available at different manufacturers.

3.4.3 Pendulum movement

Figure 24. TIG weld [30]

TIG-welding is well known for its unique technic for filling the welding grooves, and our welding rig needs to replicate this resolute shown in Figure 24, this makes for a challenge because our rig does not have a programmable robotic arms with multiple joints. For our rig to be successful and used in the company's daily routine it need to replicate a hand welding result like the one shown in Figure 24Figure 24. TIG weld [30]. Despite this challenge appearing impossible with our budget and resources, we figured out a great solution to this problem. We thought that we could create an alternating rotational motion, so the tungsten electrode would move with a small radius in the groove, and that this would come very close to the welding pattern needed.

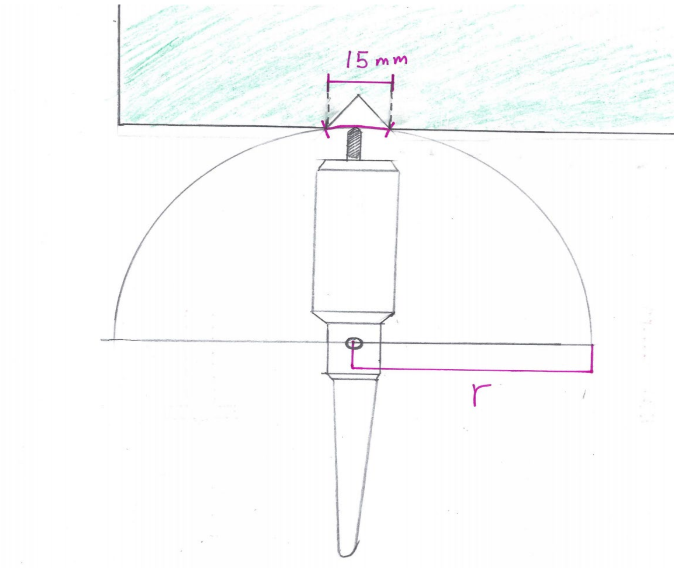


Figure 25. Sketch showing radial motion

As Figure 25 shows, by having the welding gun rotating around a fixed point the tungsten electrode would move on this radial path and fill the groove. The next step in designing this mechanism is to calculate where to place the rotation point and how to create this alternating rotational motion.

Figure 25 shows the rotation point to be in the center of the gun, but that is just for the sake of visualizing the idea. In reality, we must have the rotation point further back because of the unnecessary complications that would occur if we built the rotation in the gun handle. The idea builds upon having an electric motor driving this mechanism, so we must think very carefully where to place the motor. TIG welding generate strong magnetic fields, so placing electronics close to the arc requires caution and expertise. Our choice of motors would be either a standard electric motor or a slightly more advanced stepper motor. The stepper motor has an advantage because of the option to program it to our liking but the standard motor being much easier to set up. Yet bout motor has a different approach on how to create the desired motion.

Figure 26. Electrical brush motor [31]

The first idea builds upon Figure 26. Electrical brush motor [31]. These types of motors are very straight forward, just connect it to a power source and it starts turning. However, we desire an alternating and smooth motion, so some actions must be taken to ensure that. Figure 28. Stepper motor [32]

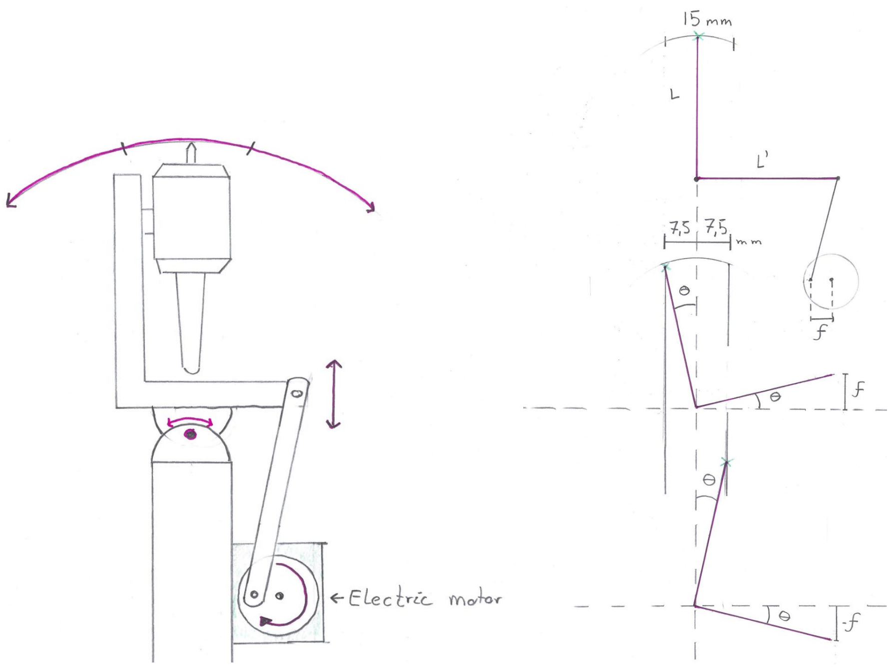


Figure 27. Pendulum movement with an electrical brush motor.

Figure 27 illustrate the base idea for the use of and standard electrical motor to create the pendulum motion. This design has a hinge at the end of the "arm" where a separate holder for the welding gun is placed. The motor drives a disk connected to rod, which then converts rotational motion into linear motion, inspired by how pistons work in an engine. The displacement *f* determines the angle θ, which then determines the curve length. This sketch shows the maximum pendulum distance of 15 mm, but it needs to be able to move less and with a suiting speed. Thus, we thought of having the disk or rod adjustable to be able to achieve a smaller motion. As well as using a transmission on the motor and limiting the power supply to control the rpm on the brush motor.

Figure 28. Stepper motor [32]

We will not go into detail on how the stepper motor works, but the main difference is that these types of motors can be programmed to rotate in steps.

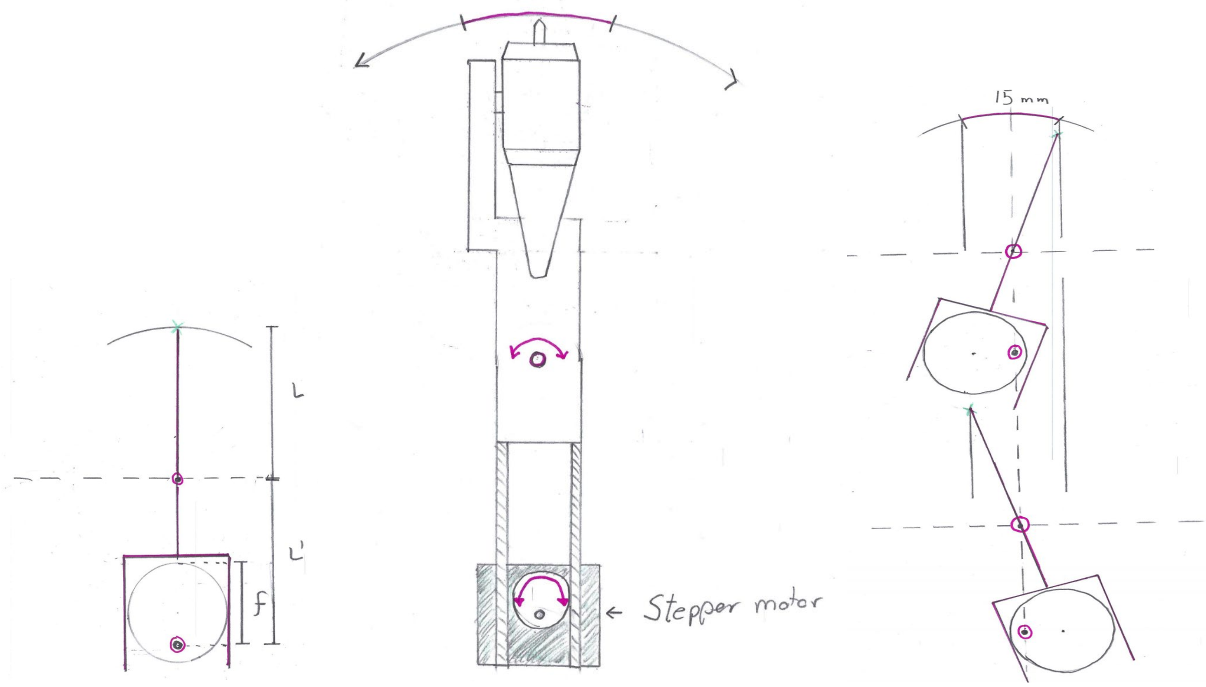


Figure 29. Pendulum movement with a stepper-motor illustrated.

The principle behind the stepper motor design is to have a solid part rotating on a pin, being pushed for side to side by an off-center rotating disk. The stepper motor is placed on the vertical centerline with the disk fitted on top rotating in a groove. With this design the displacement ***f*** is determined by the dimension of the off-center disk. Then there is the programming part, the stepper motor can be programmed to know its location. So, the idea is that we program it to rotate ±90°, in center there is no displacement and on ±90° we have maximum displacement. The operator can limit the travel range by adjusting how many degrees the motor turns, making this design capable of filling every welding groove in our size range.

A setup with the brush motor requires no programming and because of that it makes it harder for the operator to control the zigzag motion. A setup with the stepper motor gives the operator more control and adjustment abilities, but much more electrical expertise build. Regardless of which motor we choose our main concern is the possibility of damages on the electrical equipment caused by the electromagnetic radiation for the welding arc. Every electrical wire must be protected from radiation interference to minimize the risk for electrical failure. The motor and control units also need protection, so we thought of using EMC boxes to protect these parts. And just in general be aware of where the electric current flows in the construction and redirect them away from the essential parts.

To summarize our thoughts on choice of motor. Our team has the most trust in the stepper motor to achieve the best results to our requirements. Its highly controllable with programming, easily adjustable and has a slimmer design.

3.4.4 Spring and roller

To ensure top quality result every time our rig is used, we figured out that it would need a component which helps ensure consistent welding. The tungsten electrode must keep a constant distance to the workpiece for it to weld properly. If for some reason the pipes have an uneven diameter or defects on them our rig needs to cope with it and still weld to a perfect result. So, the idea is that we build an arm with a roller on which always has contact with the workpiece and keeps a constant distance for the tungsten electrode. And the spring in this mechanism will work like a car suspension, where the suspension always works on keeping the tire in contact with the asphalt instead her the spring works on keeping the roller in contact with the workpiece. The whole idea I based on the roller arm moving the welding gun closer or farther away from the workpieces depending on the differences in diameter, but it also need to be a compact and versatile design to cope with the different welding situations.

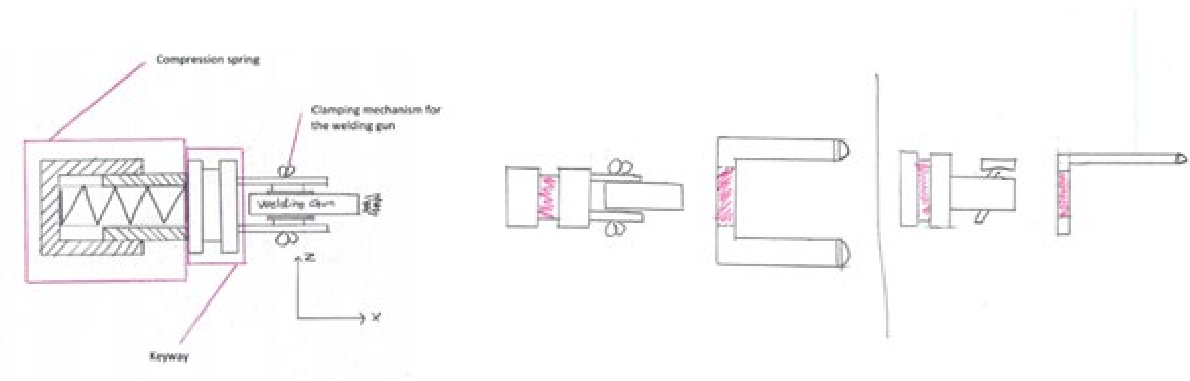


Figure 30. First draft of linear spring and roller system, with detachable roller

Figure 30 shows our first sketch for the spring and roller system. At that point we had not merged the idea with the zigzag mechanism. It is a difficult deign part to merge these to mechanism without losing some of the benefits they provide. The zigzag motion is the highest priority to be functional and the spring and roller system must adapt to or decisions regarding the zigzag motion. As Figure 17 shows the red zone where the rig should be able to weld, we see that the welding position can vary a lot so a linear spring might not be the best solution for the roller. However, the roller needs to be detachable for abnormal welding situations, like welding in tight spots on the flange.

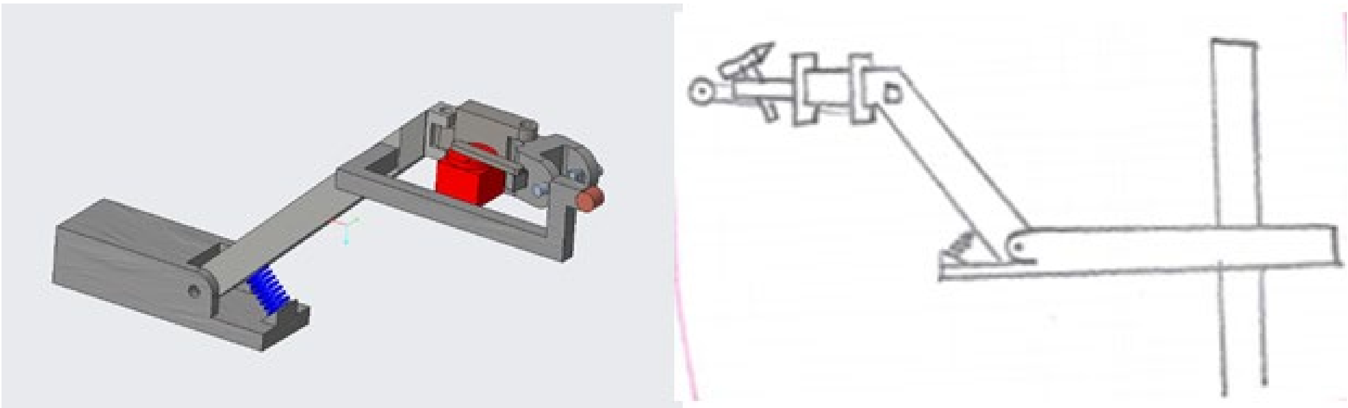


Figure 31. Angled spring and roller with electric brush motor.

Figure 31 is a spring and roller design merged with the brush motor setup, with an angled beam mounted on the end of the “arm”. In this design, the weight of the construction keeps the roller in contact with the workpiece, and when the roller is being pushed back the whole arm tilts backwards then spring pulls back to the resting position. This deign works best with a 45° angle of attack over the horizontal line on the workpiece. This design does not work straight on; however, we were informed that its preferred with an angle of attack above the horizontal center line. Not shown in the model but the roller arm is supposed to be adjustable and removable in this design as well, using z-screws to adjust and locking it in place.

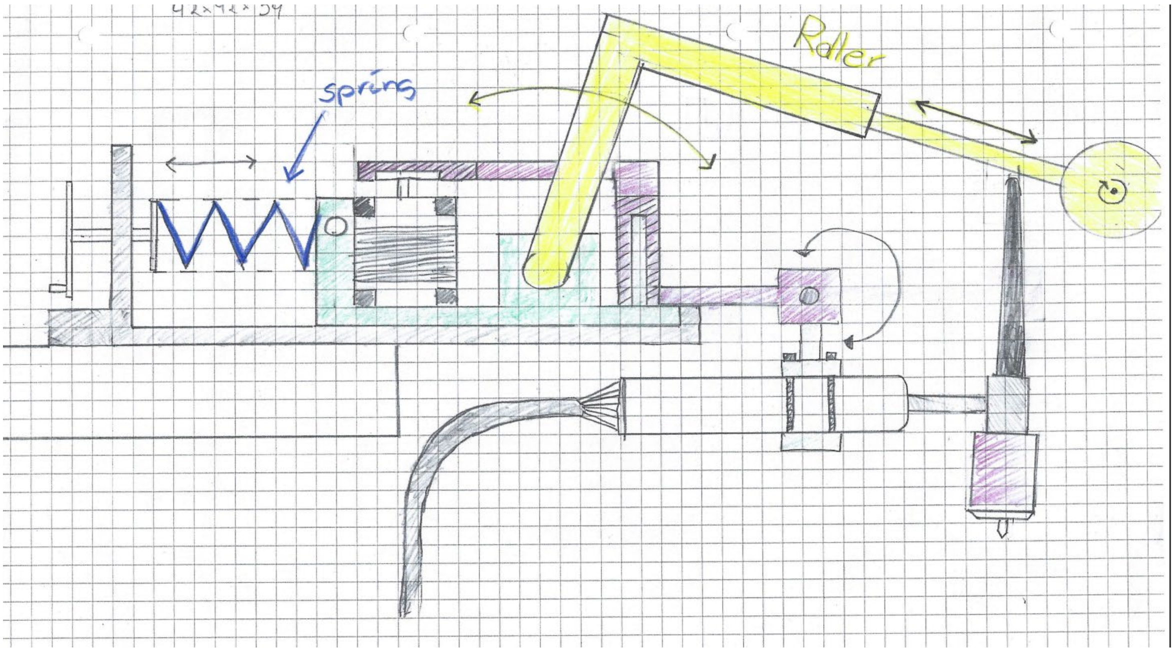


Figure 32. Stepper motor setup with linear spring and roller

Figure 32 shows a merger between the stepper motor and a linear spring. This design has a spring tighter for pre tightening the roller to the workpiece before welding, and the green hub slides on top of the grey part which is mounted to the "arm". As previously mentioned, we are unsure how good the linear spring will work when welding above center.

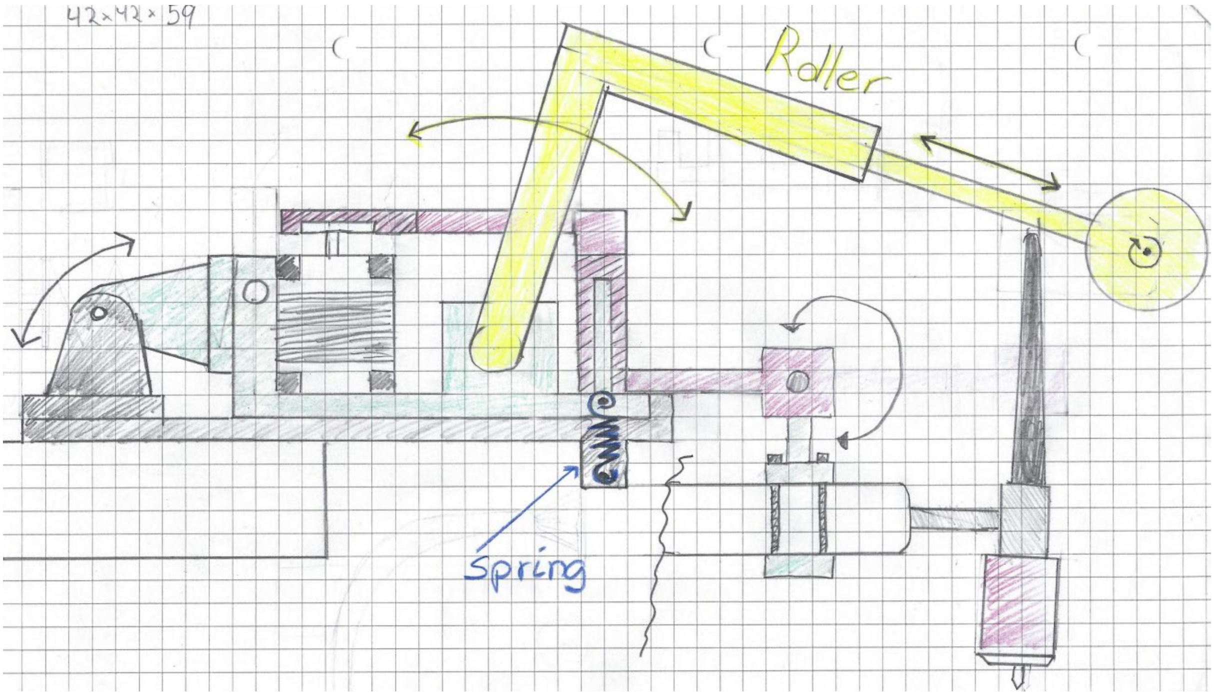


Figure 33. Stepper motor setup with a hinged hub, spring and roller.

Figure 33 shows a merger between the stepper motor and hinge setup for the spring. The idea is that when roller is pushed back the green hub would start to rotate around the hinge at the back, and the spring in front would pull it back to resting position. This also works best at an angle of attack above center. But both Figure 32 and Figure 33 have slimmer and more versatile design then the tilted beam idea.

Overall, we find that the idea in Figure 33 would achieve the best result for our requirements. It has the slimmest design and is the most capable for abnormal welding situation, with its highly adjustable roller arm and a spring system with high performance above center. It is easily merged with the other components that together makes up the *Gun mechanism.*

4 Engineering

From the ideas above, based on the pros and cons, we have concluded on the following solution for our prototype. When prototyping, practical and realistic thinking is very important. A design solution may look nice on the screen but on the other hand, it could be very hard to make. Therefore, we have done a lot of work adjusting the design so that it is easy to machine and assemble.

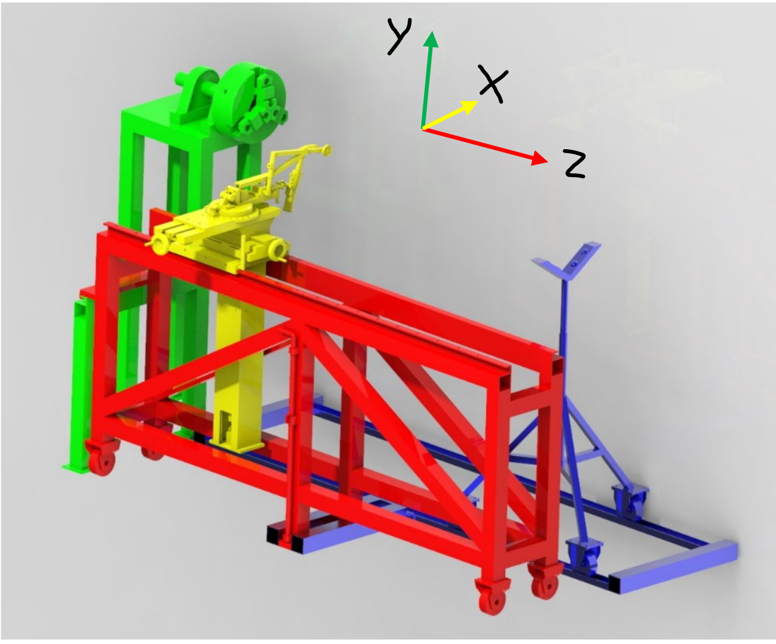


Figure 34. The four main modules

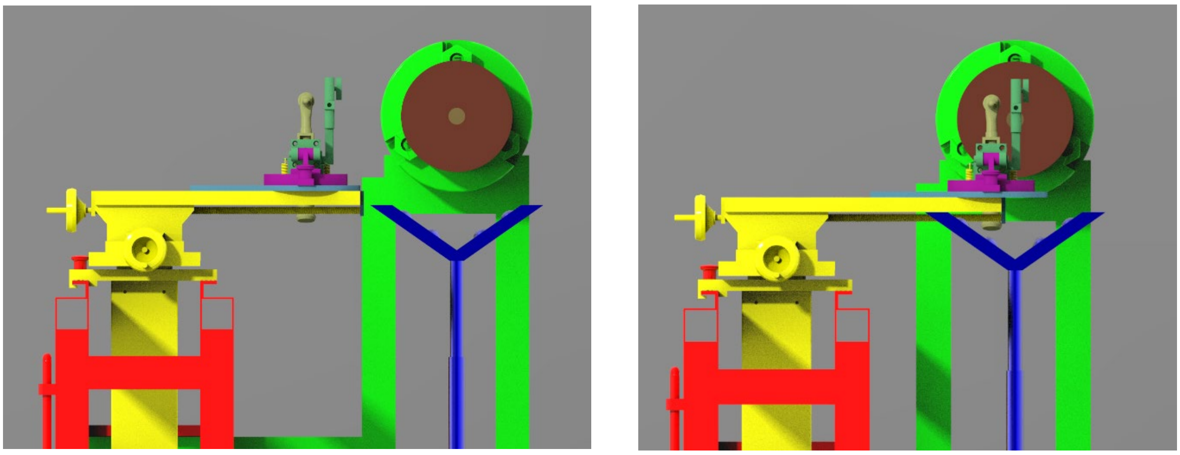
As illustrated in Figure 34 the welding rig will consist of four main modules. A table with chuck (green), a sliding bed (red), an adjustment module (yellow) and a standing rest on rails (blue). These four modules are only locked by bolts and can easily be moved in separate operations. This is an advantage when assembling and practical if the rig needs to be moved around in the workshop.

4.1 Table

On the table there is an electric motor, rpm manipulator, gearbox, connecting shaft and chuck. The size of the table is reduced to the minimum to occupy less space. Welded square-pipes makes a reliable construction which is easy to assemble. By bolting the table to the ground stability will not be an issue.

4.2 Sliding bed

The table is connected to the sliding bed but not locked. The bed will able to move in the direction of the X-axis Figure 34. Four wheels ensures a stable and low friction movement. The square pipes on the floor and guideway fastened to the table will keep the bed in place relative to the framework on the ground. The ability to move is necessary if the operator wants to rotate the gun 90 degrees and weld on the surface of a flange close to the center of the pipe. For such an operation the movement of the XZ-table will not be enough. In Figure 35 the advantage of moving the sliding bed is shown. As you can see, the blue plate on the XZ-table also needs to be moved to reach inner position.



a) *b)*

Figure 35. Sliding bed movement a) Outer position b) inner position

On top of the bed the guideways are placed. For this purpose, we considered polished cylindrical ways Figure 14 and other high precision variants. We also discussed having wheels between a flat surface and the sliding module. These alternatives are not very robust which it should be in a workshop where heavy pipes are involved. We ended up making it as simple as possible. The movement is not needed to be accurate since its only purpose is to roughly place the welding gun. The final design therefore consists of two steel angle bars Figure 36. One for guiding and one for support. This will be locked by a spring locking pin.

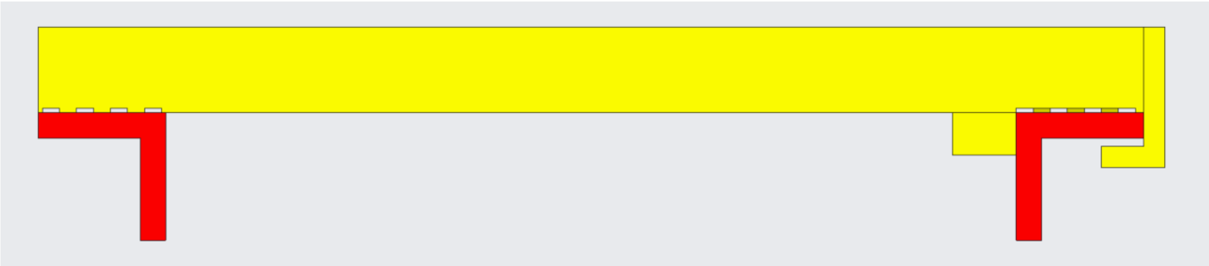


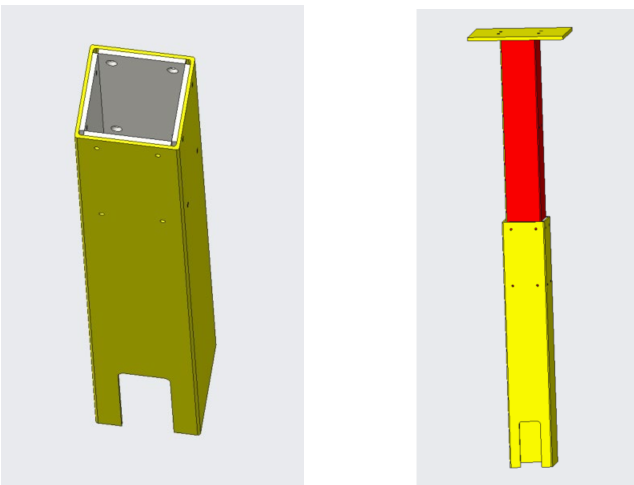
Figure 36. Angle bars (red color) for support (left) and guiding (right)

4.3 Adjusting module

In the middle of the sliding bed the adjusting module is located. This module is the most advanced and therefore the one we have used most of our time working on. Any precise movement of the welding gun is operated from here. The main requirements for the adjusting module are to move the welding gun in all XYZ-directions, rotate the gun around the Y-axis and allow the gun to operate with a pendulum movement.

4.3.1 Height adjustment

For the overall height adjustment (Y-axis, Figure 34) we have considered two different designs Figure 20. The first is a standing tower with an arm sliding up and down. This design is a stable design and makes it easy to attach a lifting mechanism. The disadvantage is the operator's loss of clear view. The dynamic tower solution is not fastened like the static one and requires good construction stability to prevent it from wobble. In our opinion, the clear sight for the operator is a great advantage. We have designed a stable dynamic tower, using a 100x100 [mm] square pipe sliding inside a 120x120 [mm]. The red pipe Figure 37 is guided by four plates inside the yellow pipe. When the tower is lifted to maximum is has 200 [mm] surface contact with from the guiding plates. This will keep the tower stable when operating above center pipe position.



a) *b)*

Figure 37. Illustration of height adjustment a) 120x120 pipe with bushing b) 100x100 pipe inside

To produce the lifting work required we studied a pinion and rack mechanism locked by a worm gear. A worm gear has a high reduction ratio and will therefore make the work added to rotate the hand wheel small. On the other side, the velocity of the moving tower will be low. Worm gears often appears in heavy-duty jacks which is an engineering overkill for our purpose. An option would have been to design our own worm gear housing. As a result of the amount of work required to make our own housing, we started looking for better solutions.

Electric actuators use a turning leadscrew to create a movement. They are not too expensive and appears in a wide range of lifting capacity. The electric motor can easily be connected to a switch for adjusting height. We found an actuator on the internet that lifts 60kg which is about 20 kilogram above our required amount. It has a stroke length of 500mm which fits our requirements [33]. The long stroke length is necessary when welding from top as illustrated in Figure 38. The actuator is placed in the middle of the sliding bed as showed in Figure 39.

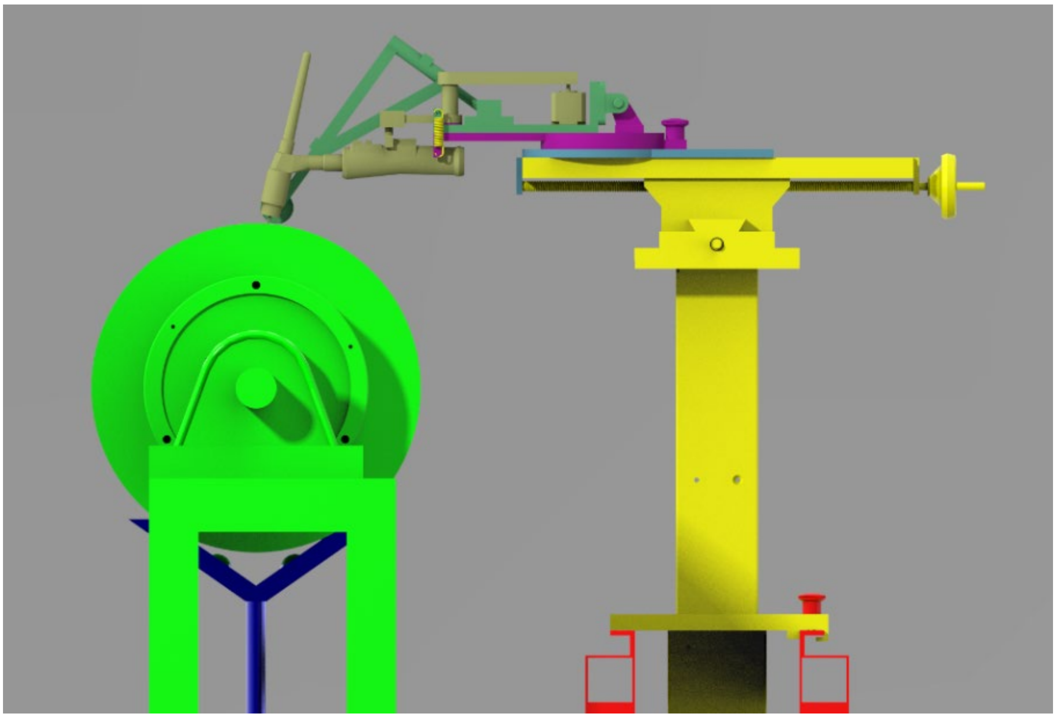
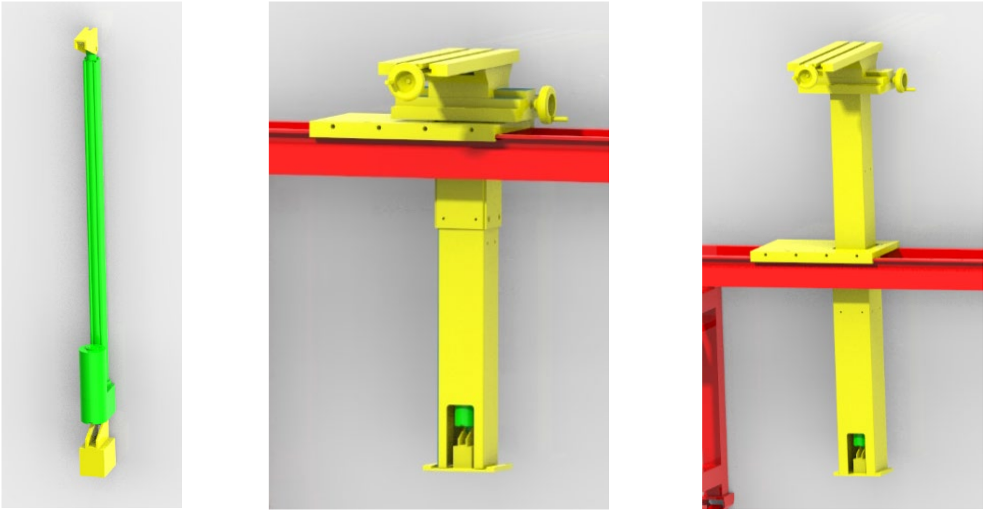


Figure 38. Welding from top on pipe with diameter 400mm



a) b) c)

Figure 39. a) Lifting actuator b) Zero stroke length position c) Full stroke length position

4.3.2 Adjustment in XZ – direction

For adjustment in both X- and Z-directions Figure **34** we need a solution which can be operated while welding. We considered using the pinion and rack for this purpose. Since we need an accurate adjustment when filling small welding grooves, the slack in the pinion rack was unwanted.

The threaded screw became a better solution. It can be made with a small lead angle to achieve a precise movement. Since the operator must be able to move the welding gun in both X- and Z directions, a two-axis milling table met our requirements very well. The leadscrew is protected from any dirt inside the table, which will improve its lifetime. In Figure 40, the XZ-table is shown.

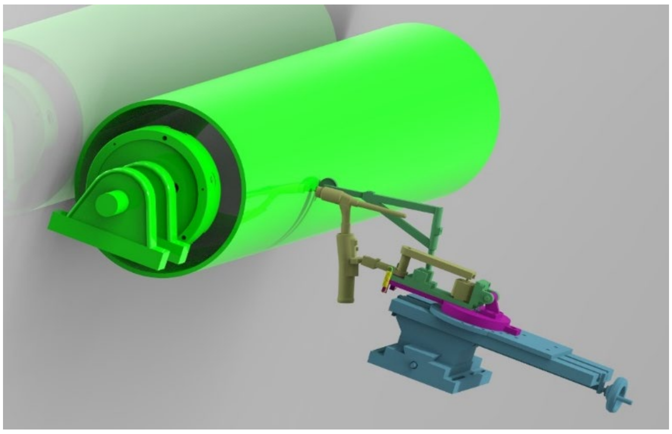


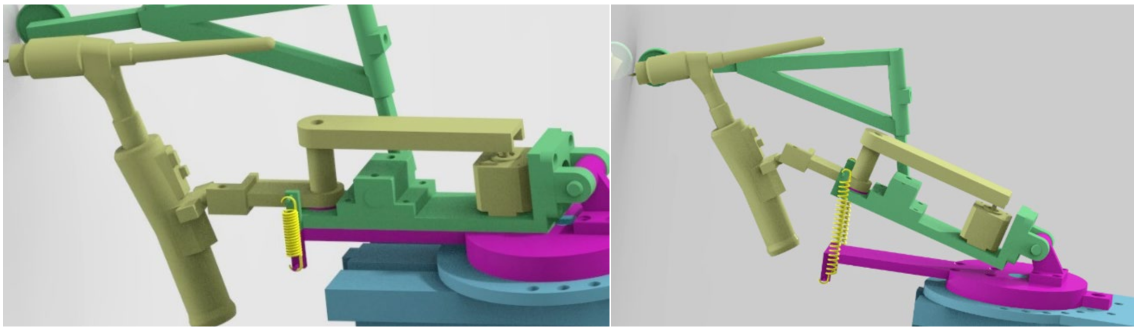
Figure 40. Illustration of XZ-table and gun welding 90 degrees on pipe

4.3.3 Spring/roller system

Early in the process, we came up with the idea of having a spring/roller system to account for off-center rotation of the pipe. We have been through a lot of different ideas according to this problem. First, we thought of having an angled spring/roller solution Figure 31. The spring had to be placed far away from the gun and we started looking for a design where the spring was operating closer and more direct on its mission. The second option was a linear roller/spring solution Figure 32. Unless we were to tilt the entire arm this design will only work when welding 90 degrees on the pipe from the side as illustrated in Figure 40.

Our latest design is a spring/roller design which only works when welding above the center of the pipe. From welding theory 2.5, we know that the gun will be tilted above center to get the best result Figure 17. In other words, our design fits the actual welding angle.

As illustrated in Figure 41 the green colored part will be lifted in a circular path when pushing the roller against the pipe. The lifting part is hinged to the purple part, as you can see to the right of the picture Figure 41. The spring marked by yellow color will assist gravity to keep the roller attracted to the pipe.



a) *b)*

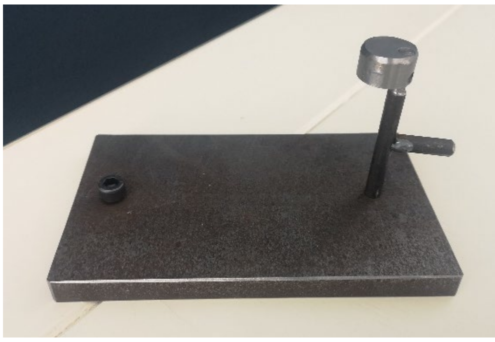
Figure 41. a) No off-center rotation of the pipe b) Huge off-center rotation of the pipe

4.4 Pendulum movement

When welding in deep grooves a pendulum movement from side to side is necessary to fill the space with welding material. This mechanism has been a challenging part in our project. Obviously, it must be able to operate close to a high temperature zone, vary in speed and pendulum stroke length.

We decided to go with a stepper motor solution illustrated in Figure 41. And to verify if this design works, we built a prototype (Figure 42 a and b, Figure 43) for testing the principal behind it. With great functionality we concluded on using the stepper motor. The benefits using the stepper motor concept are that it has a very slim design and contains few touchy components. The motor is also placed with some distance to the welding area, to prevent electrical components from failing during welding. With the stepper motor we can easily change both the speed and the pendulum stroke length. To do so we use a control panel with a rpm-switch and a switch adjusting the degrees the cam rotates, both programmed into an Arduino chip.

a)



b)

Figure 42. a) Steppermotor mechanism prototype b) Off – center cam rotated by hand

Figure 43. Testing the mechanism with welding gun

4.5 Support underneath the pipe

For support underneath the pipe we have chosen to reuse the standing rests from Figure 13. As you can see in Figure 34 the standing rest is placed on rails which lays one the floor. These rails are bolted to the table and will be aligned in center of the chuck. This way the operator knows that the pipe is in center when it is placed in the middle of the rest. The rails are connected to two square pipes for guiding of the sliding bed.

4.6 Final design

The final model is presented in Figure 44. A model of a man is inserted, as well as a gearbox and an electric motor, all to illustrate the scale and what it would look like in real life. You can see in the figures below that the controls for the rig is at a nice working height for the average man. This helps to prevent injuries and makes the overall use of the rig more convenient and user friendly.

The shiny colours seen in the figures represents the stainless steel material that is going to be used for building it.

There are two things missing from the final design representations. The wiring to the welding gun and the electrical component box with all its wires. This is mainly due to the fact that the issues on where to put them was agreed to be delayed until the rig was built. This is so that they could be placed at the optimal places depending on where the rig was placed in the workshop.

Figure 44. Final design of the welding rig with worker for scale. Pipe diameter 350 mm, length 2000 mm.

Figure 45. View of gun mechanism

Figure 46. Rig seen from the side

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5.1 Figure list

5.2 Table list

6 Attachment

All parts are made of stainless steel, unless otherwise stated on the drawing.

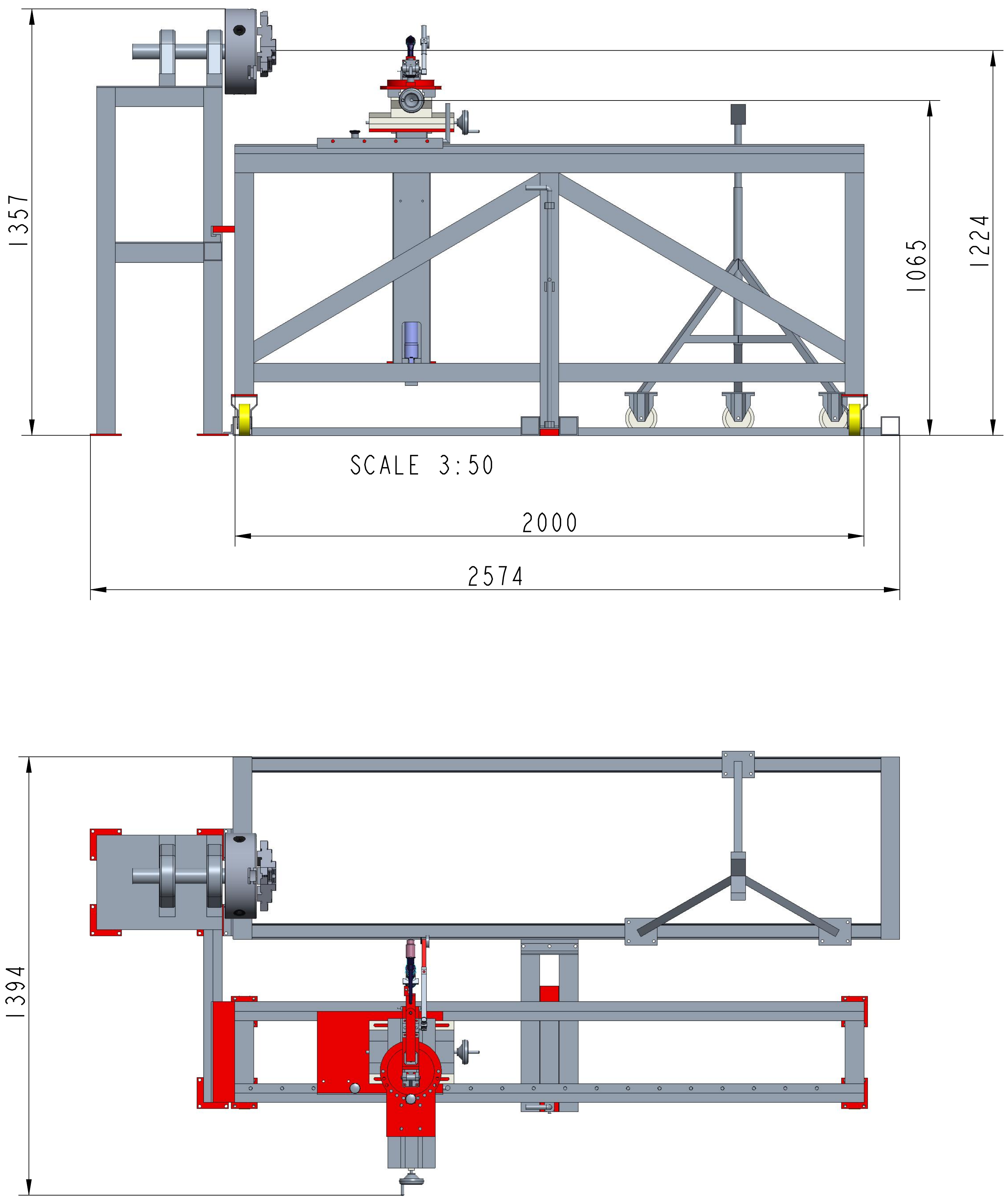
Drawings

Order list for BRIAS

Del	Link	Antall/lengde	Material	Kommentar
Fjær til rollers	https://www.biltema.no/	1 Pakke		
Hengsle til vippeplate	https://no.rs-online.com/	1 stk		RS stock no: 192-8583
Hjul til bein under vanger	https://no.rs-online.com/	4 stk		RS stock no: 253-5952
Hjul til støtte	https://no.rs-online.com/	3 stk		RS stock no: 787-1503
XY-bord	https://www.gustavsenas.no/	1 stk		Axminster CT1
T-spor mutter	https://verktoybutikken.no/	4 stk		Dimensjon 12. Størrelse M10
Låsepinn	https://www.wixroyd.com/	2 stk		Order No: 32604.W0754
Bolteskåte	https://www.p-lindberg.no/	1 stk		Art. nr 9053755
Kjoks		1 stk		Kjøp den som passer bedriften best
Øyebolt til løft	https://www.wixroyd.com/	4 stk		Order No: 18864.W0010
Firkantrør til rammeverk, dim. 60x60x3	Fritt val av forhandlar	min. 27 meter (5x6 meter)	Rustfritt	Rammeverk
Firkantrør til hev og senk, dim. 120x120x4	Fritt val av forhandlar	minimum 1 meter	Rustfritt	
Firkantrør til hev og senk, dim. 100x100x4	Fritt val av forhandlar	minimum 1 meter	Rustfritt	
U-profil til støtteskinne, 50x25x5x6	https://www.damstahl.no/	minimum 4 meter	Rustfritt	Varenr: 30620
Firkantrør til ruller, dim 15x15x1,5	For eksempel: Smith stål	ca 1 meter	Rustfritt	
Vinkeljern 30x30x6	Fritt val av forhandlar	min 5,4 m (1x6 meter)	Rustfritt	
Actuator	https://www.amazon.com/	1 stk		500mm stroke
Bryter til actuator	https://www.amazon.com/	1 stk		
Monteringsbrakett actuator	https://www.amazon.com/	1 stk		
Steppermotor	https://www.kjell.com/	1 stk		
3-trinn bryter	https://www.kjell.com/	1 stk		
Trinnmotordriver	https://www.kjell.com/	1 stk		
Panelpotensiometer	https://www.kjell.com/	2 stk		
Strømbryter	https://www.kjell.com/	1 stk		
Strømforsyning	https://www.amazon.com/	1 stk		24V 100W

Drawings and raw material list for BRIAS

Navn	**antall**
Firkantror_120x120x4_bunnplate	1
Feste_topplate_opp_firkant_100	2
Festeplate_sideguide	1
Firkantror_120x120_festebrakett	4
p_plate_til_hub	1
p_rotasjons_arm_del_a	1
p_rotasjons_arm_del_c	1
p_ruller_glidestykke	1
p_vegg_vippeplate	1
p_vippeplate_del_a	1
Festeplate_stottebein	3
plate_på_xy-sleid	1
p_rotasjons_hub	1
p_firkantror_60x60_topplate	1
Hovedplate_hovedsleid	1
p_bord_feste_til_gulv	5
festeplate_til_bein_bunn	4
flattjern_styring_bakke	1
L_skinne_innside	1
Totalt antall deler	32
POM-emner til maskinering:	
200x100x6	4
53x60x30	1
Stangemner til dreiing (ferdigmål):	
Ø15 x 120	
Ø20 x 60	
Ø20 x 30	
Ø15 x 140	Ei stang på Ø20/Ø30 dekker alt
Ø15 x 60	
Ø30 x 10	
Ø20 x 40	

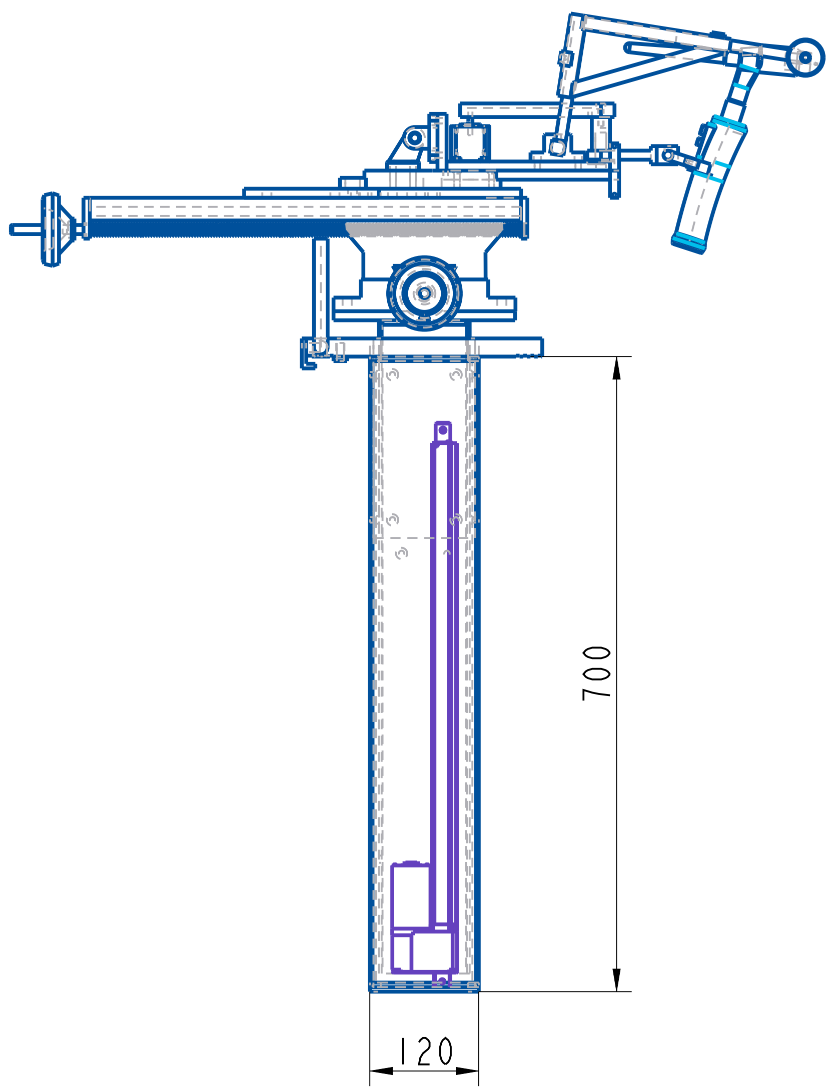


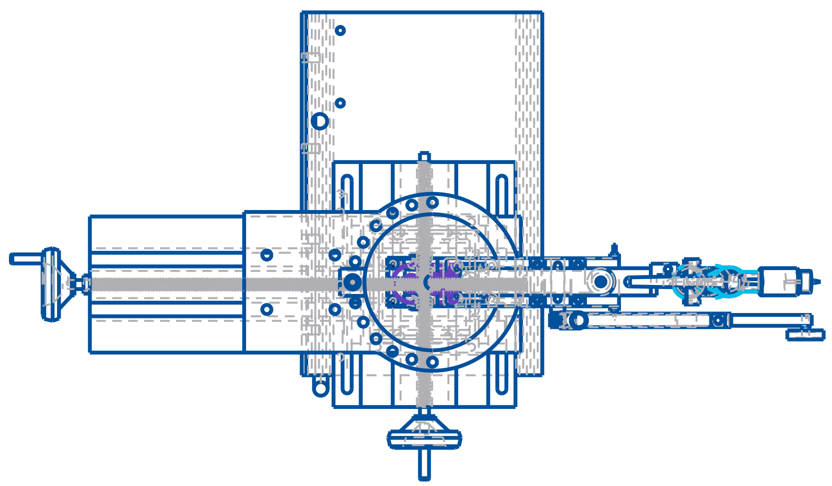
Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
35	2	VINKEL_FIRKANTROR_FESTE_U			
34	1	VINKELJERN_VANGER_MED_HULL			
33	1	VINKELJERN_VANGER			
32	2	STYRINGSBLOKK_LAASING_VANGER			
31	4	SKRAASTILT_STOTTER			
30	1	SIDEGUIDE			
29	1	P_RULLER_SUB_HJUL			
28	1	P_RULLER_HJUL_SPLINT			
27	1	P_RULLER			
26	1	P_BORD			
25	1	PRODUSERBAR_PENDELARM			
24	1	PLATE_PÅ_XY-SLEID			
23	1	PINN_TIL_ROTASJON_PAA_XY			
22	2	MONTERINGSBRAKETT_ACTUATOR			
21	1	LÅSEBRAKETT_PIN_BEIN			
20	1	LAGERHUS			
19	1	KAMSKIVE			
18	1	HOVEDSLEID_MODULBASERT			
17	4	HJUL_TIL_BEIN_6STK			
16	1	GOLVSKINNE			
15	1	FLATTJERN_STYRING_BAKKE			
14	1	FLATTJERN_STOTTE			
13	2	FIRKANTROR_VANGER			
12	2	FESTE_TOPPLATE_OPP_FIRKANT_100			
11	4	FESTEPLATE_TIL_BEIN_BUNN			
10	1	FESTEPLATE_STYRING_TIL_UPROFIL			
9	1	BOLT_LÅSING_VANGER_LANG			
8	4	BEIN_STOTTE_IKKJE_SKRAA			
7	4	BEIN_MELLOM_DE_LANGE			
6	4	BEIN_FIRKANTRØR_LANGE			
5	2	BEIN_FIRKANTRØR_EKSTRA_LANGE			
4	1	AXMINSTER_CTI			
3	1	AKSLINGMEDKJOKS			
2	1	ACTUATOR_BYGGEKLOSS			
1	2	32604_W0754			

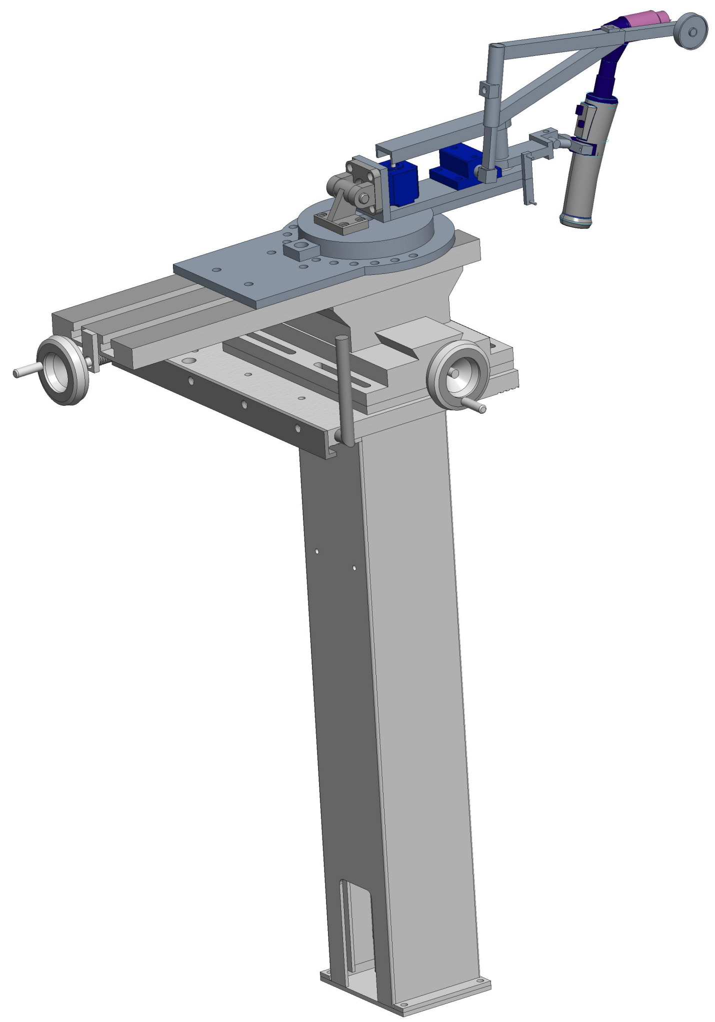
Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			3:100	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: SVEISERIGG
Beskrivelse:
Dato: 16-Mar-20
Tegning: SVEISERIGGEN





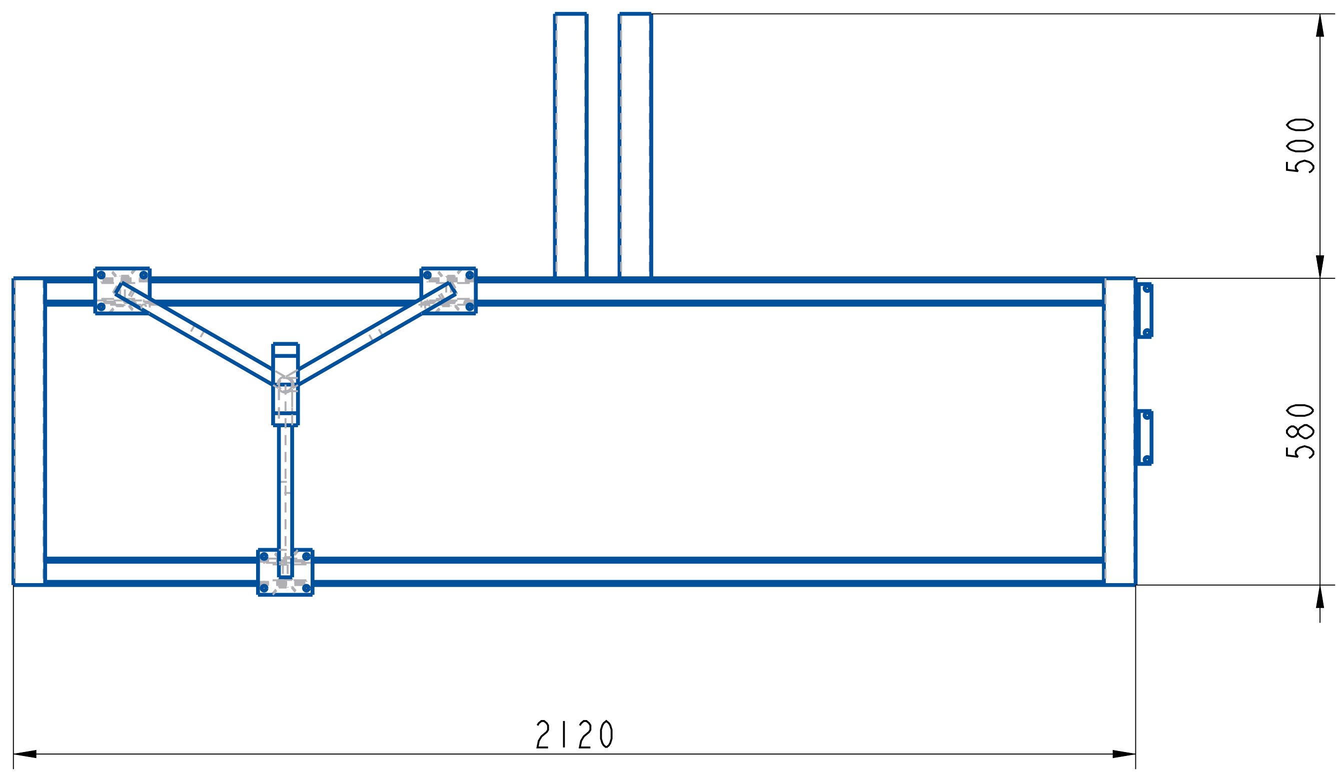


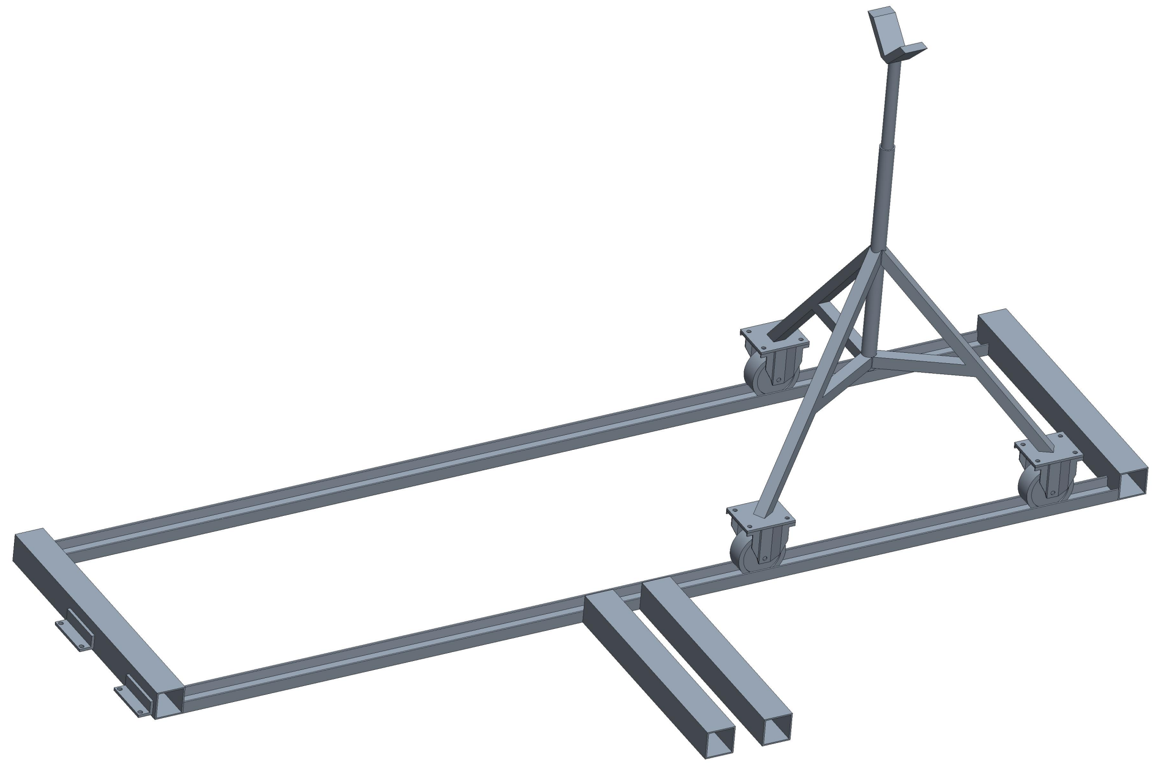
Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
6	1	P_RULLER_SUB_HJUL			
5	1	P_RULLER			
4	1	PRODUSERBAR_PENDELARM			
3	1	PLATE_PÅ_XY-SLEID			
2	1	HOVEDSLEID_MODULBASERT			
1	1	AXMINSTER_CT1			

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Eivind			3:25	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: ADJUSTING-MODULE
Beskrivelse:
Dato: 20-May-20
Tegning: ADJUSTING-MODULE





Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
5	2	U-PROFIL_STØTTE_50X25X5X6			
4	1	STOTTEBEIN_MED_HJUL			
3	2	P_VINKEL_TIL_BUNNSKINNE_DEL2			
2	2	60X60X3_GOLVSKINNE_FESTE			
1	2	60X60X3_BENKSTYRING_TOPP			

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Elvind			1:100	A3	1(1)

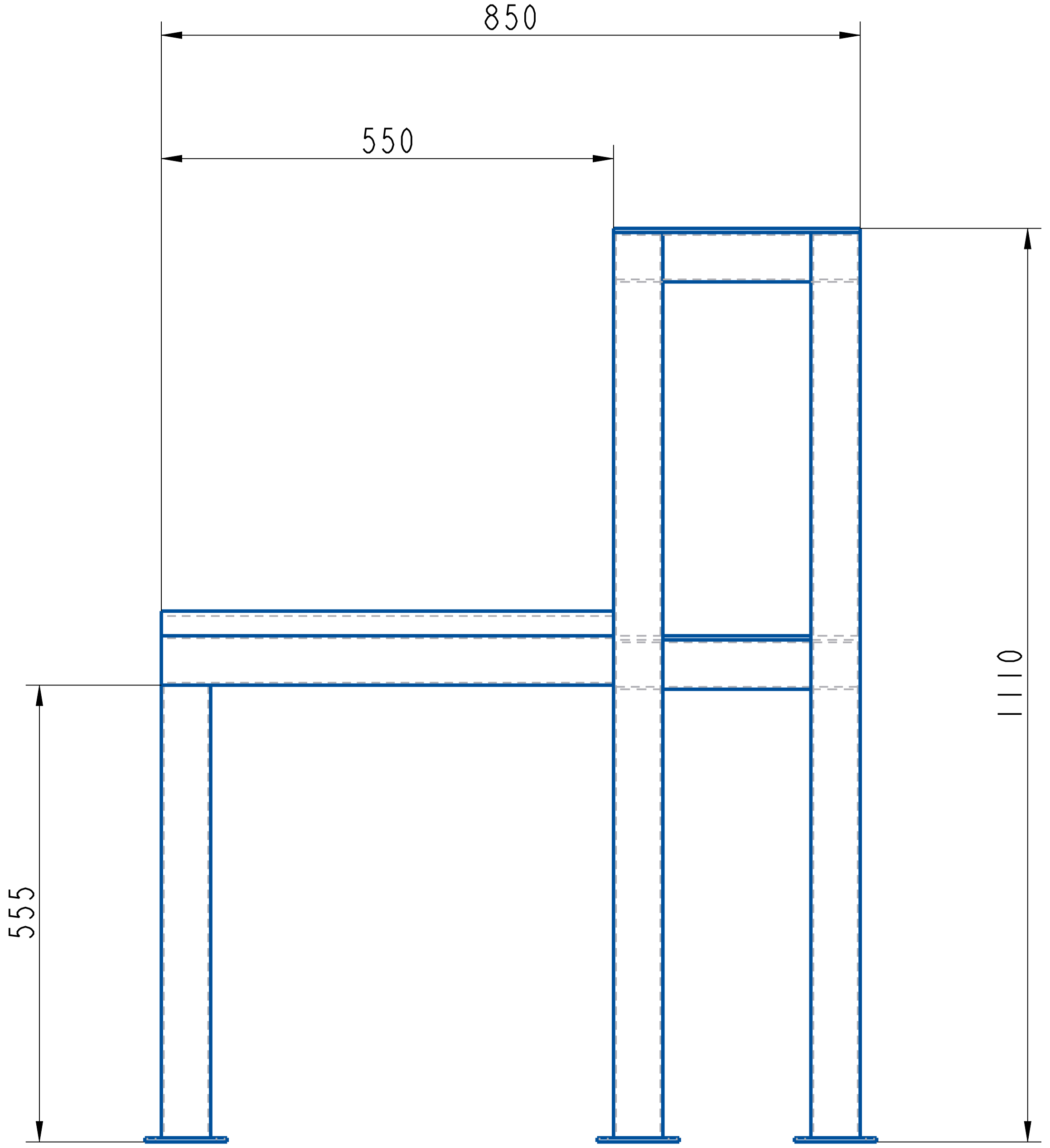
Høgskulen på Vestlandet
IMM

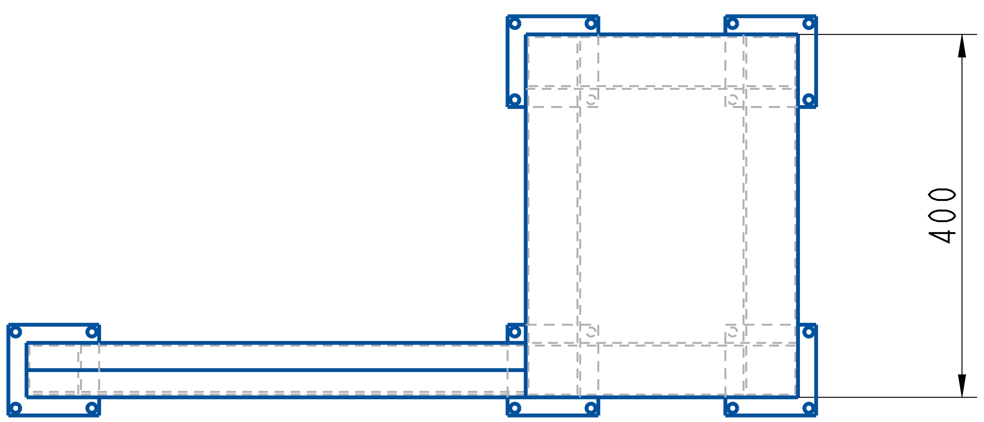
Artikell/Modell: GOLVSKINNE

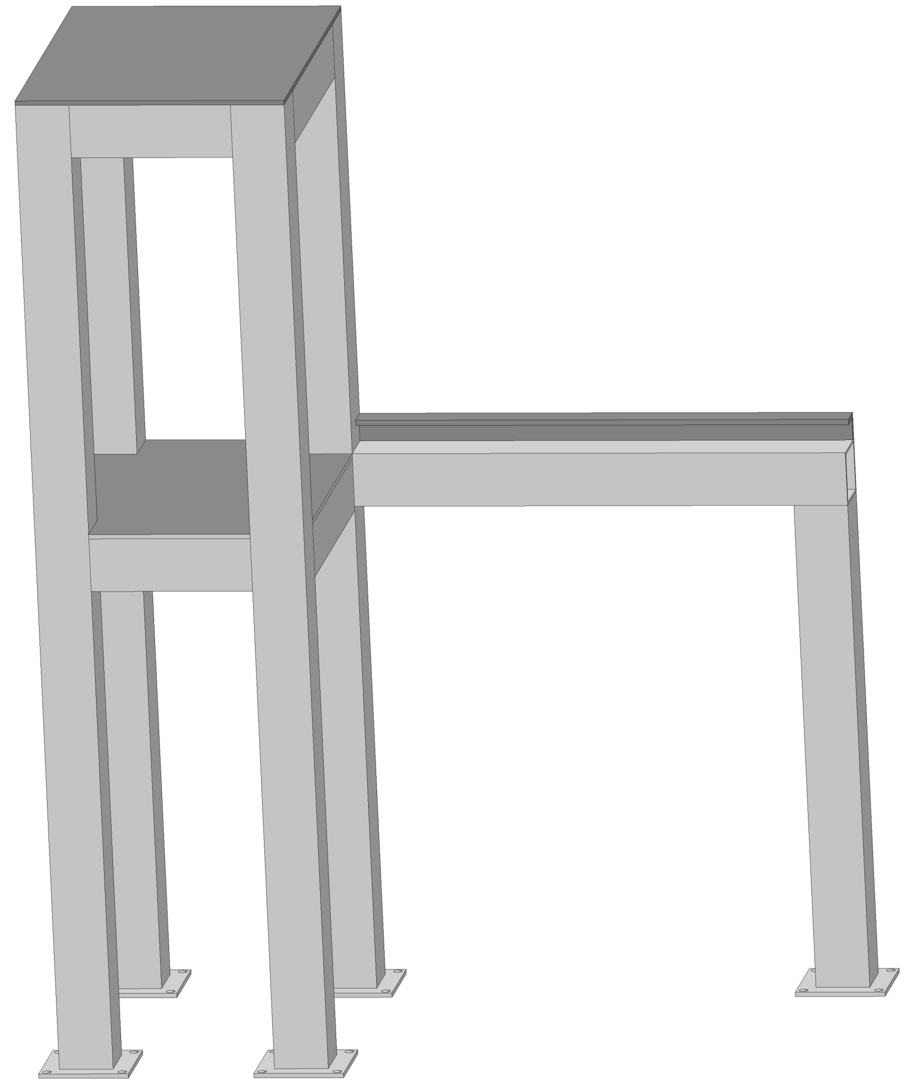
Beskrivelse:

Dato: 20-May-20

Tegning: GOLVSKINNE



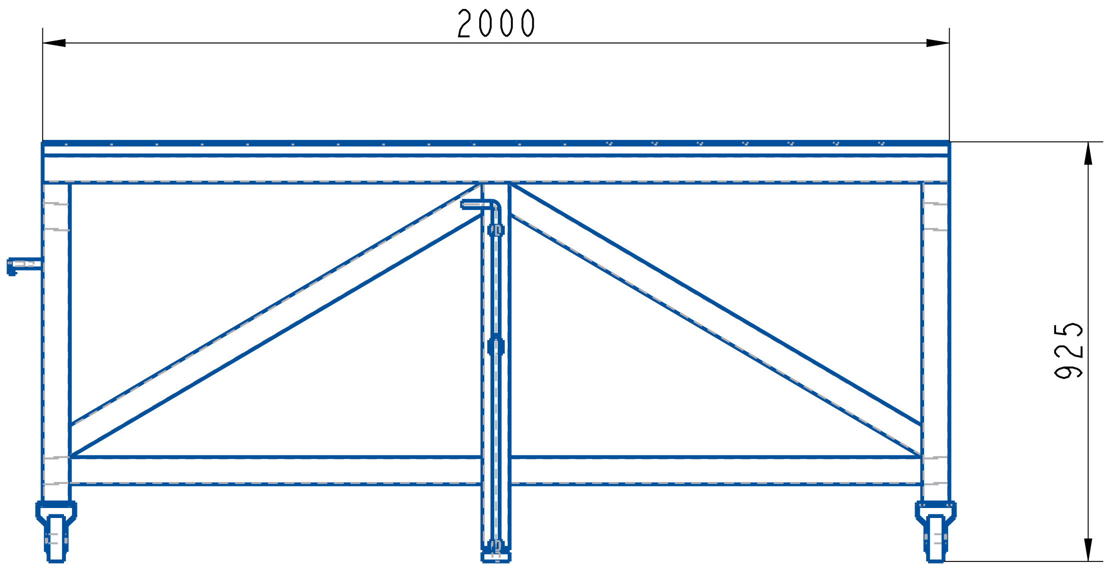


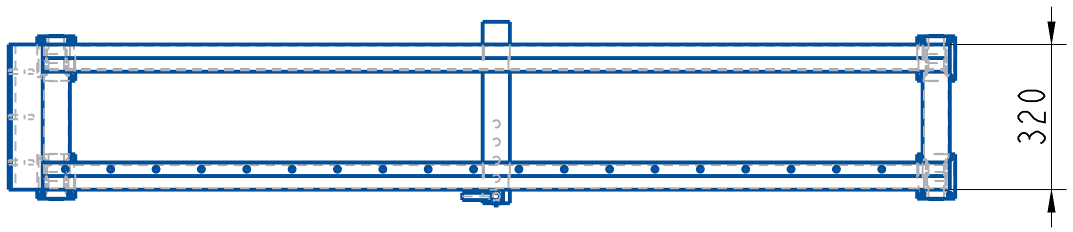


Pos	Ant	Artikkel/Modell	Beskrivelse	Materiale	Dimensjon
9	1	P_BORD_VINKELJERN_SUPPORT			
8	1	P_BORD_VINKELJERN			
7	1	P_BORD_PLATE			
6	1	P_BORD_HYLLE			
5	5	P_BORD_FESTE_TIL_GULV			
4	1	P_BORD_BEIN_TIL_SUPPORT			
3	4	P_BORD_BEIN			
2	4	P_BORD_AVSTIVING_280			
1	4	P_BORD_AVSTIVING_180			

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Eivind			3:25	A3	1(1)

Høgskulen på Vestlandet IMM	Artikkel/Modell: P_BORD	Dato: 20-May-20
	Beskrivelse	Tegning: P_BORD





Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
21	1	VINKELJERN_VANGER_MED_HULL			
20	1	VINKELJERN_VANGER			
19	2	STYRINGSBLOKK_LAASING_VANGER			
18	4	SKRAASTILT_STOTTER			
17	1	SIDEGUIDE			
16	1	P_BORD			
15	1	LÅSEBRAKETT_PIN_BEIN			
14	1	HOVEDSLEID_MODULBASERT			
13	4	HJUL_TIL_BEIN_6STK			
12	1	GOLVSKINNE			
11	1	FLATTJERN_STYRING_BAKKE			
10	1	FLATTJERN_STOTTE			
9	2	FIRKANTROR_VANGER			
8	4	FESTEPLATE_TIL_BEIN_BUNN			
7	1	BOLT_LÅSING_VANGER_LANG			
6	4	BEIN_STOTTE_IKKJE_SKRAA			
5	4	BEIN_MELLOM_DE_LANGE			
4	4	BEIN_FIRKANTRØR_LANGE			
3	2	BEIN_FIRKANTRØR_EKSTRA_LANGE			
2	1	AXMINSTER_CTI			
1	1	32604_W0754		Stainless	

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Eivind			3:50	A3	1(1)

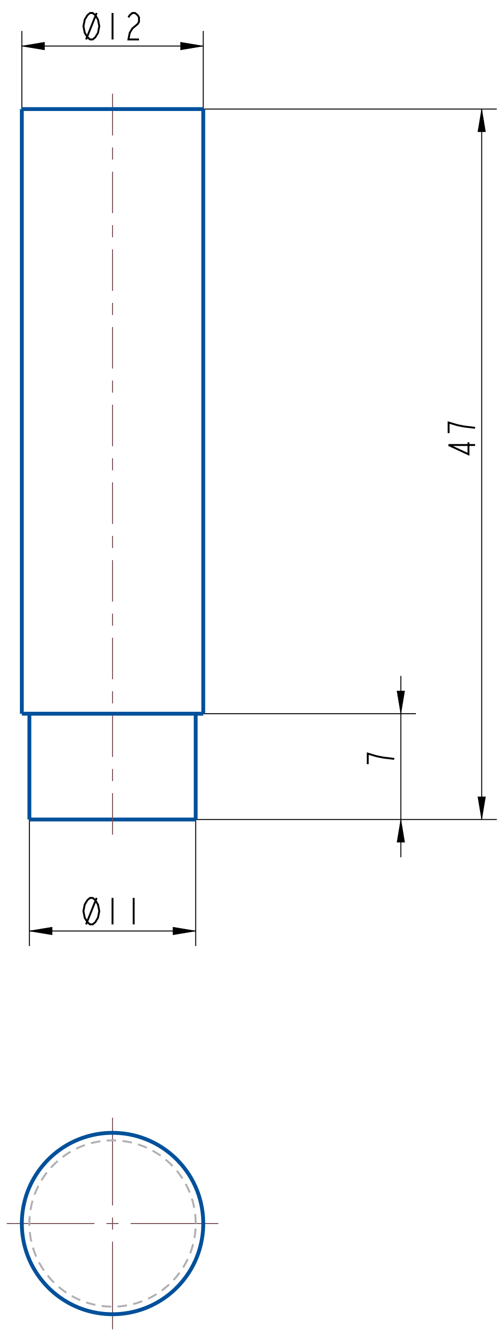
Høgskulen på Vestlandet
IMM

Artikell/Modell: SLIDINGBED

Beskrivelse:

Dato: 20-May-20

Tegning: SLIDINGBED

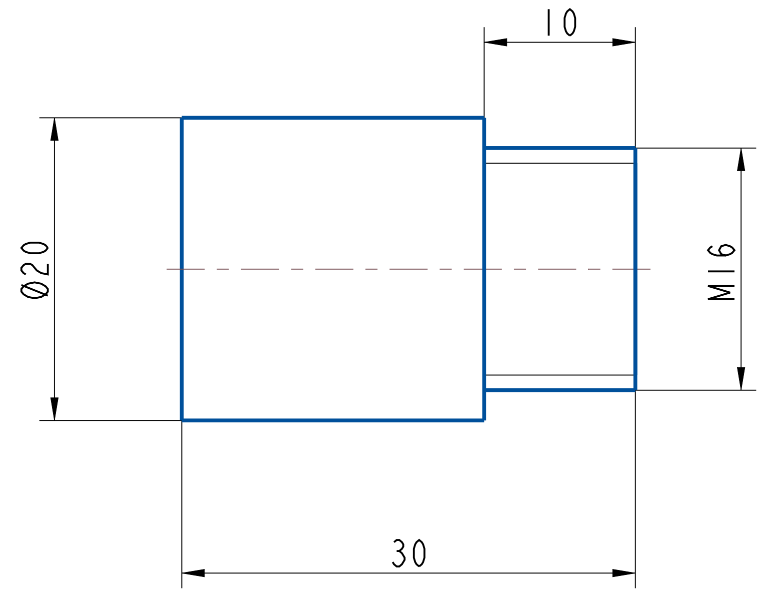


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			2:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: P_PIN	Dato: 29-Apr-20
	Beskrivelse	Tegning: DREIE_PIN

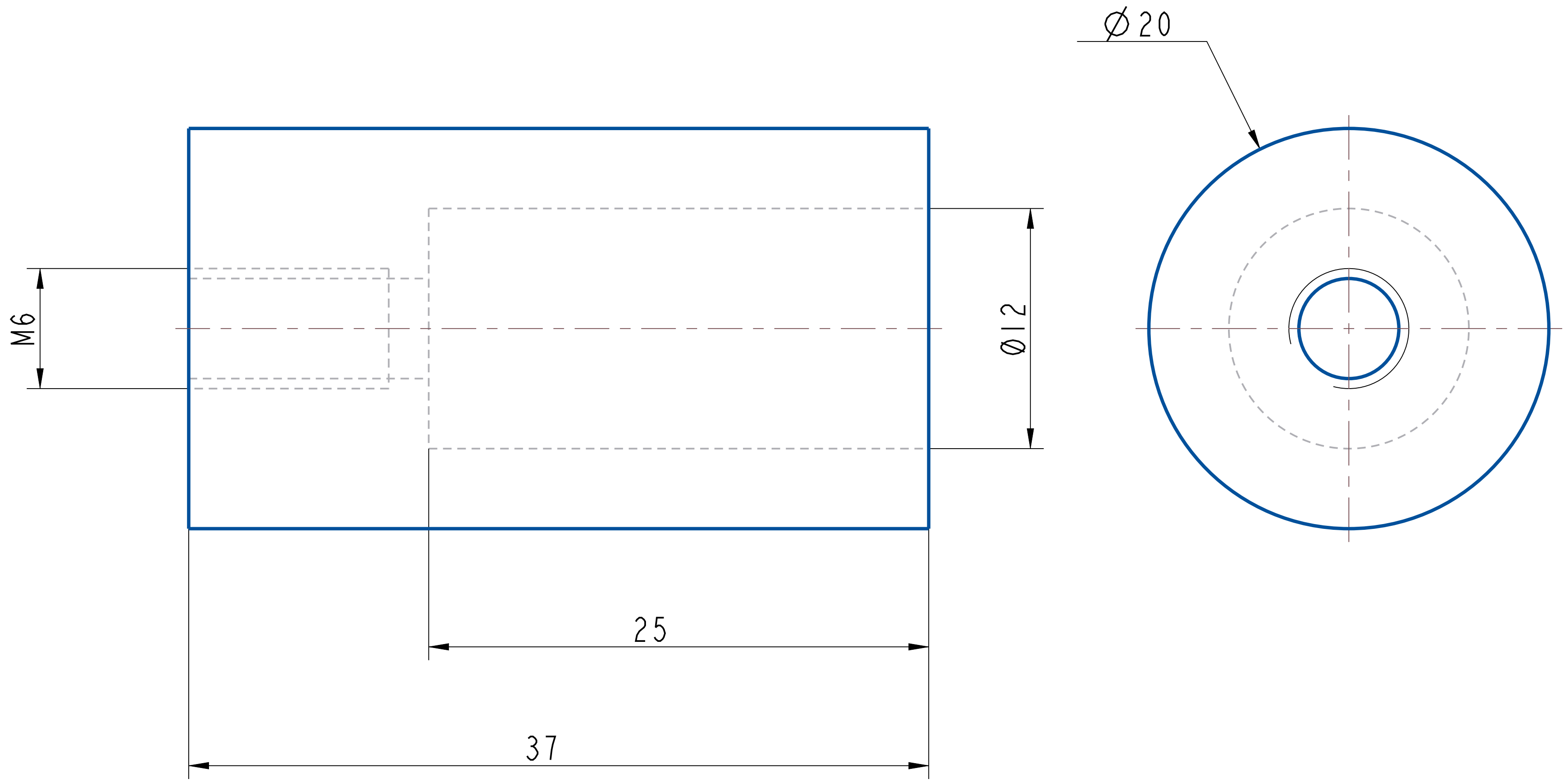


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			2:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: PINN_TIL_ROTASJON_PAA_XY	Dato: 29-Apr-20
	Beskrivelse	Tegning: DREIE_PIN_TIL_ROTASJON_PAA_XY

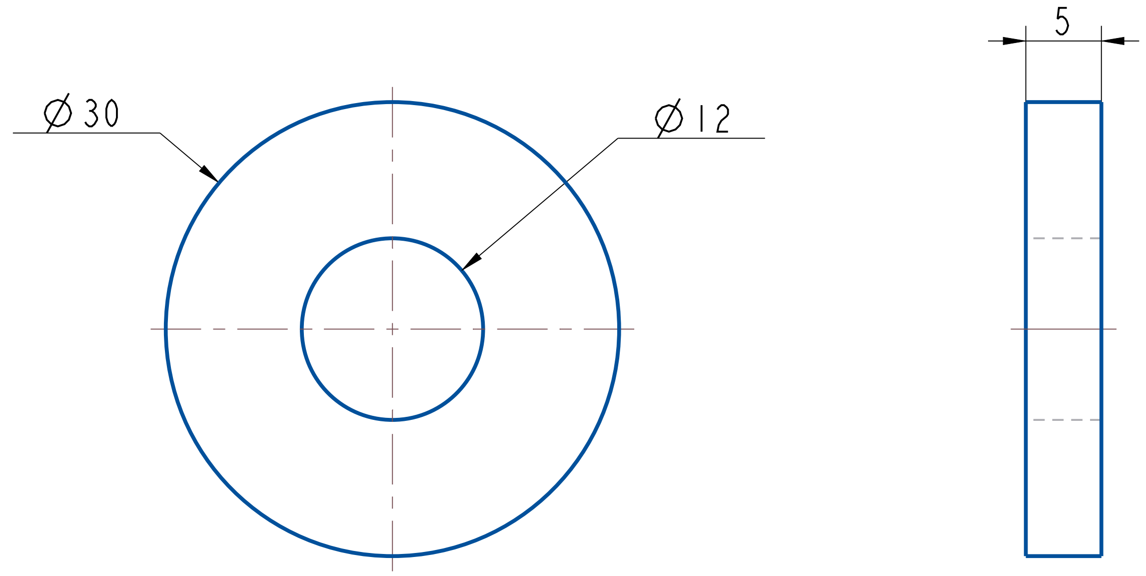


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			3:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: P_ROTASJONSARM_DEL_B	Dato: 29-Apr-20
	Beskrivelse	Tegning: DREIE_ROTASJONS_ARM_DEL_B

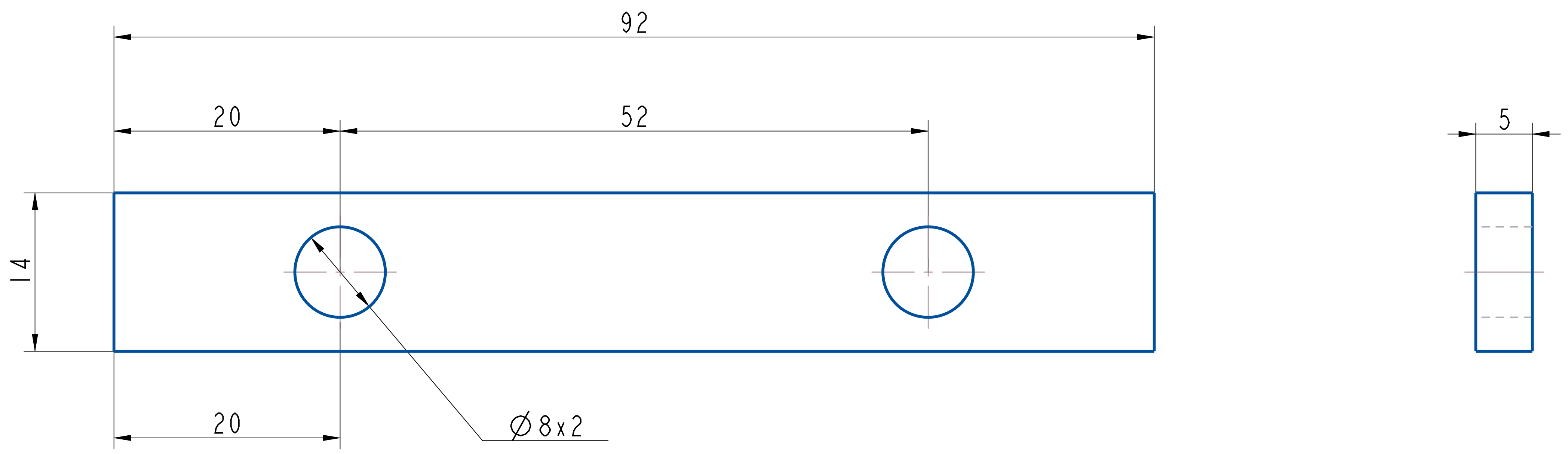


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			2:1	A3	1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell: P_SKIVE_TIL_PIN	Dato: 29-Apr-20
	Beskrivelse:	Tegning: DREIE_SKIVE_TIL_PIN

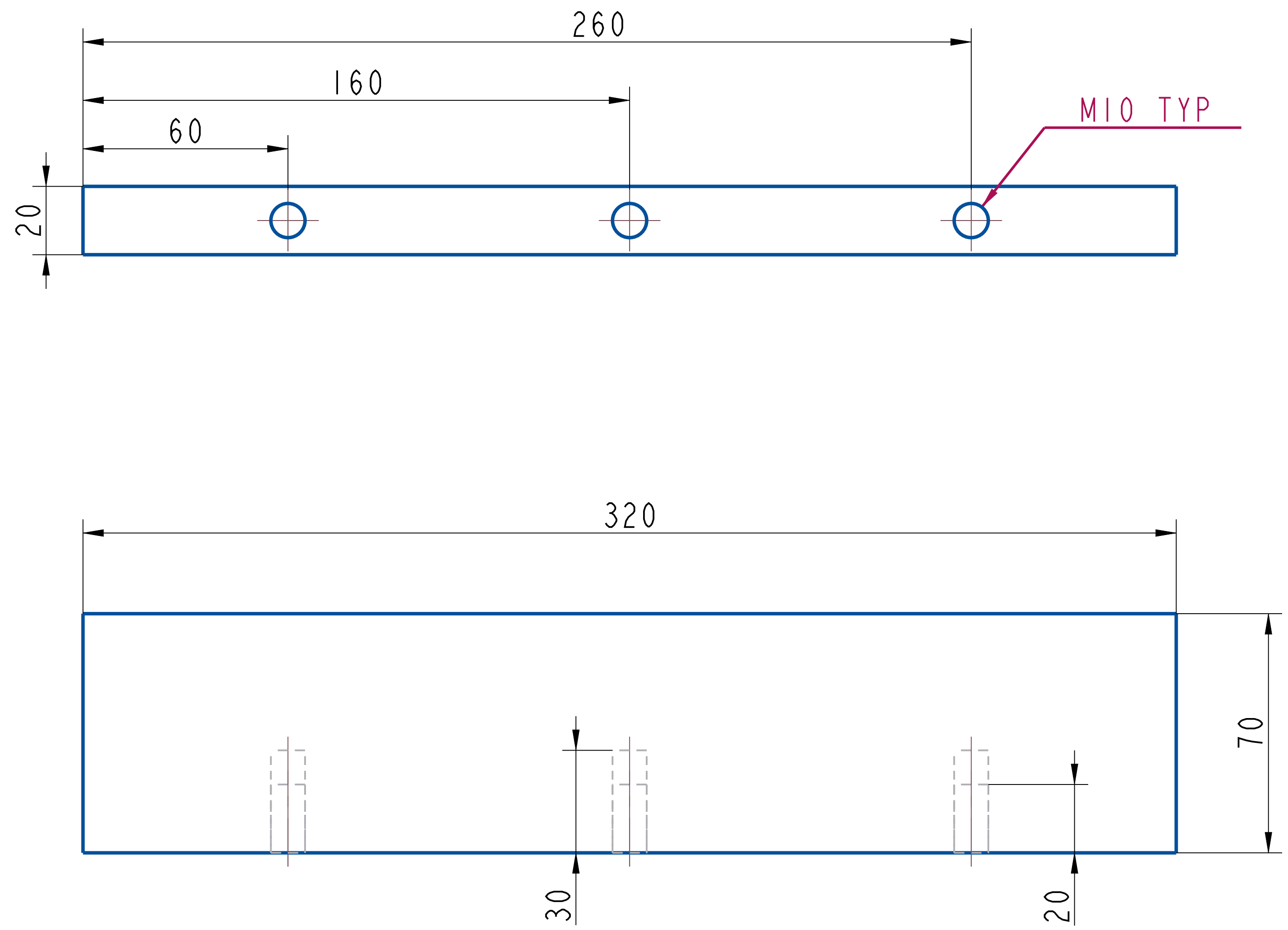


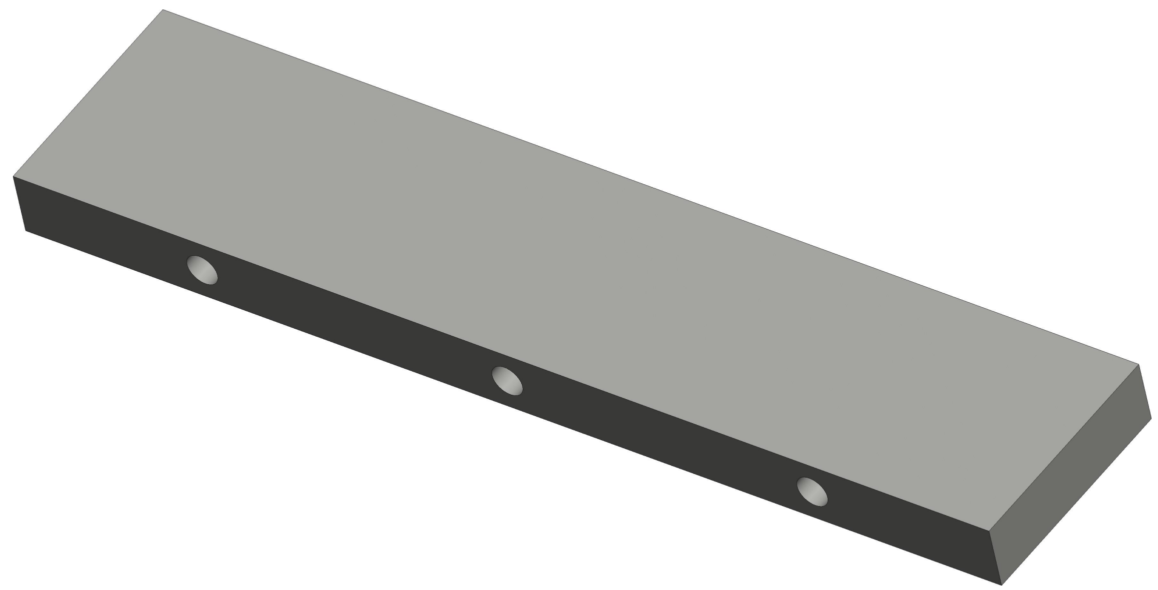
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet: Eivind	Revisjon	Vekt	Skala: 2:1	Format: A3	Blad.nr: 1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell: FESTE_TOPPLATE_OPP_FIRKANT_100	Dato: 19-Mar-20
	Beskrivelse	Tegning: FESTE_TOPPLATE_OPP_FIRKANT_100



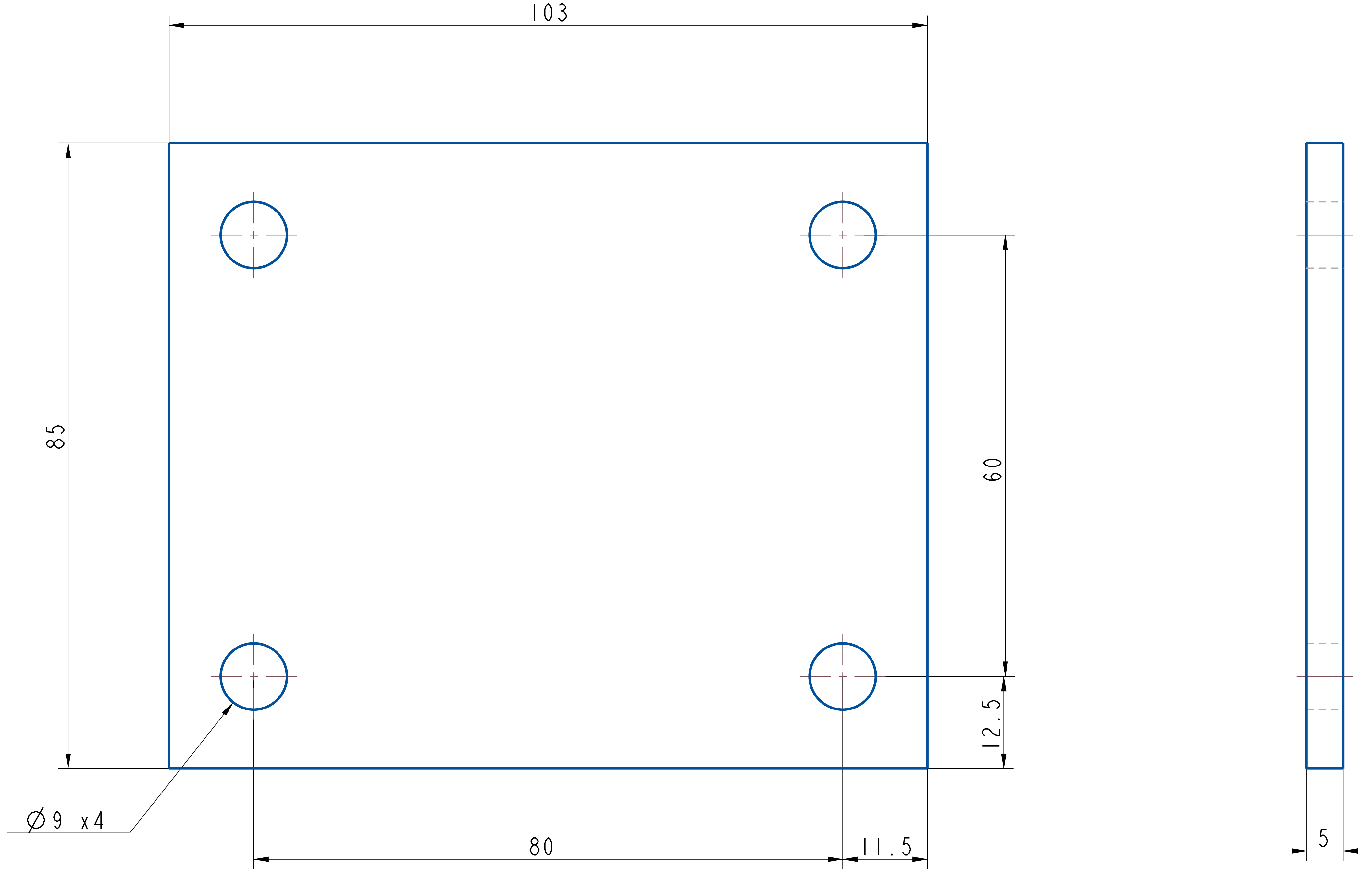


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Keivind			1:2	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell FESTEPLATE_SIDEGUIDE	Dato 19-Mar-20
	Beskrivelse	Tegning FESTEPLATE_SIDEGUIDE



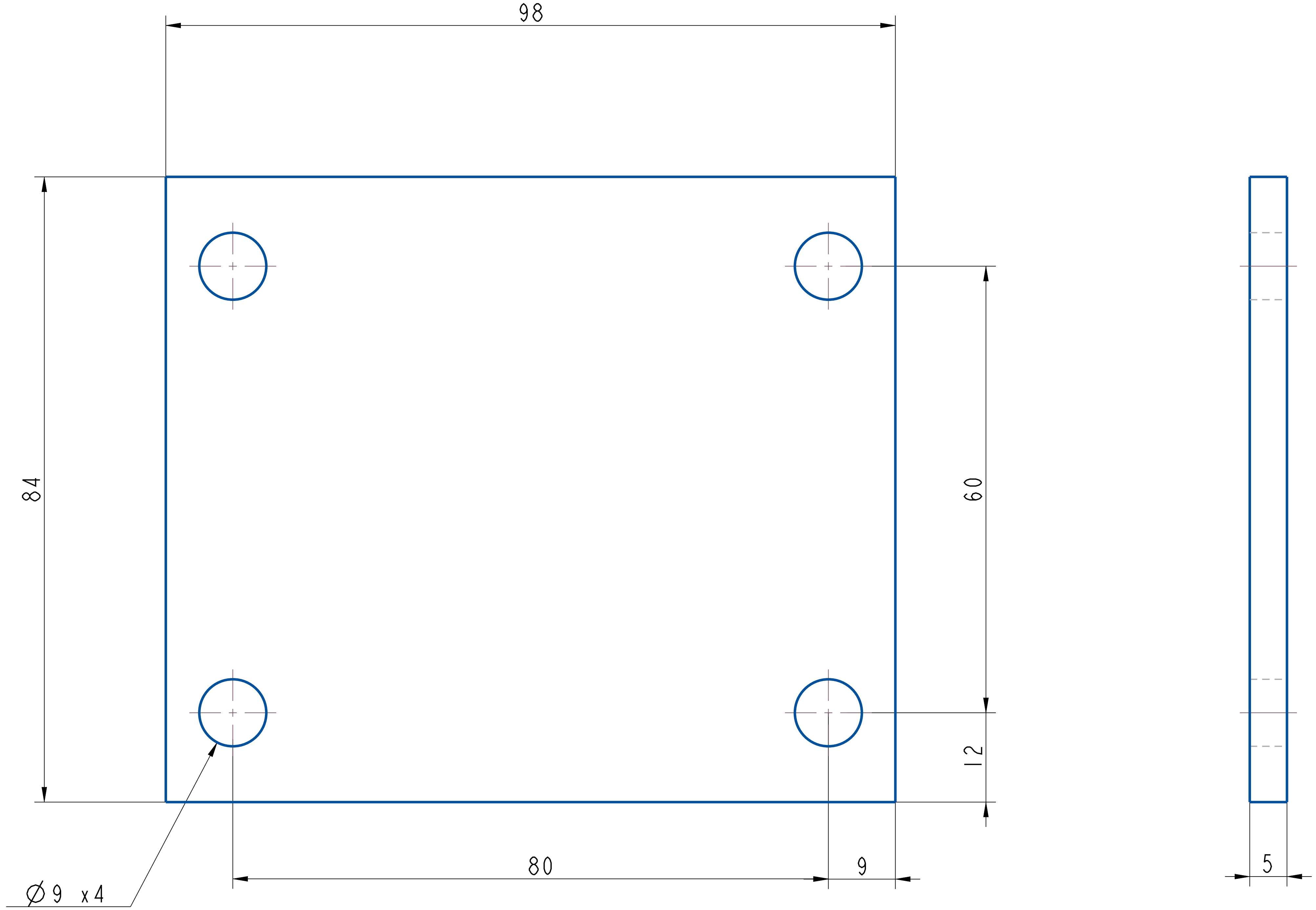
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			3:2	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: FESTEPLATE_STOTTEBEIN
Beskrivelse:
Dato: 19-Mar-20
Tegning: FESTEPLATE_STOTTEBEIN

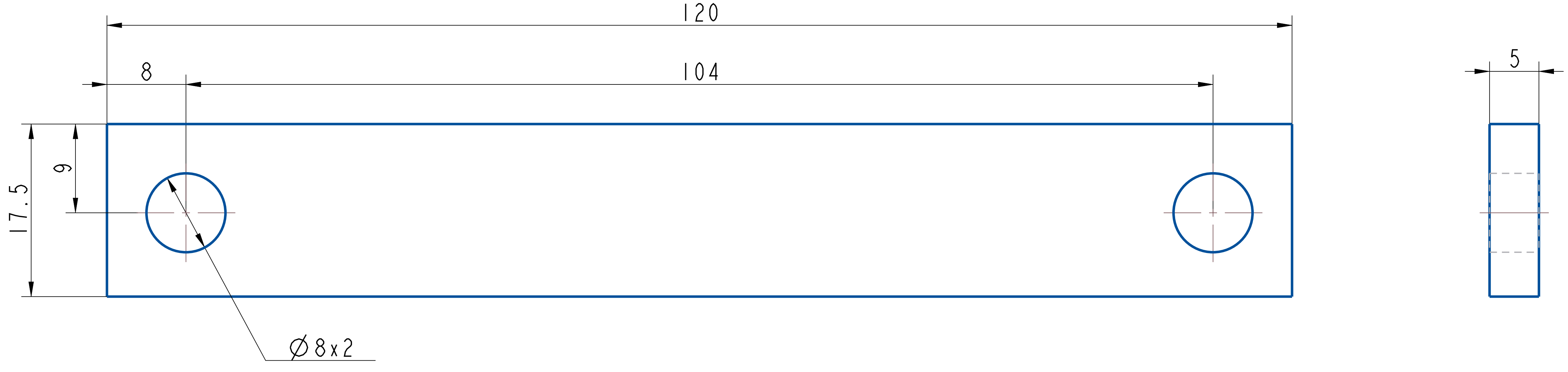


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			3:2	A3	1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell FESTEPLATE_TIL_BEIN_BUNN	Dato 19-Mar-20
	Beskrivelse	Tegning FESTEPLATE_TIL_BEIN_BUNN

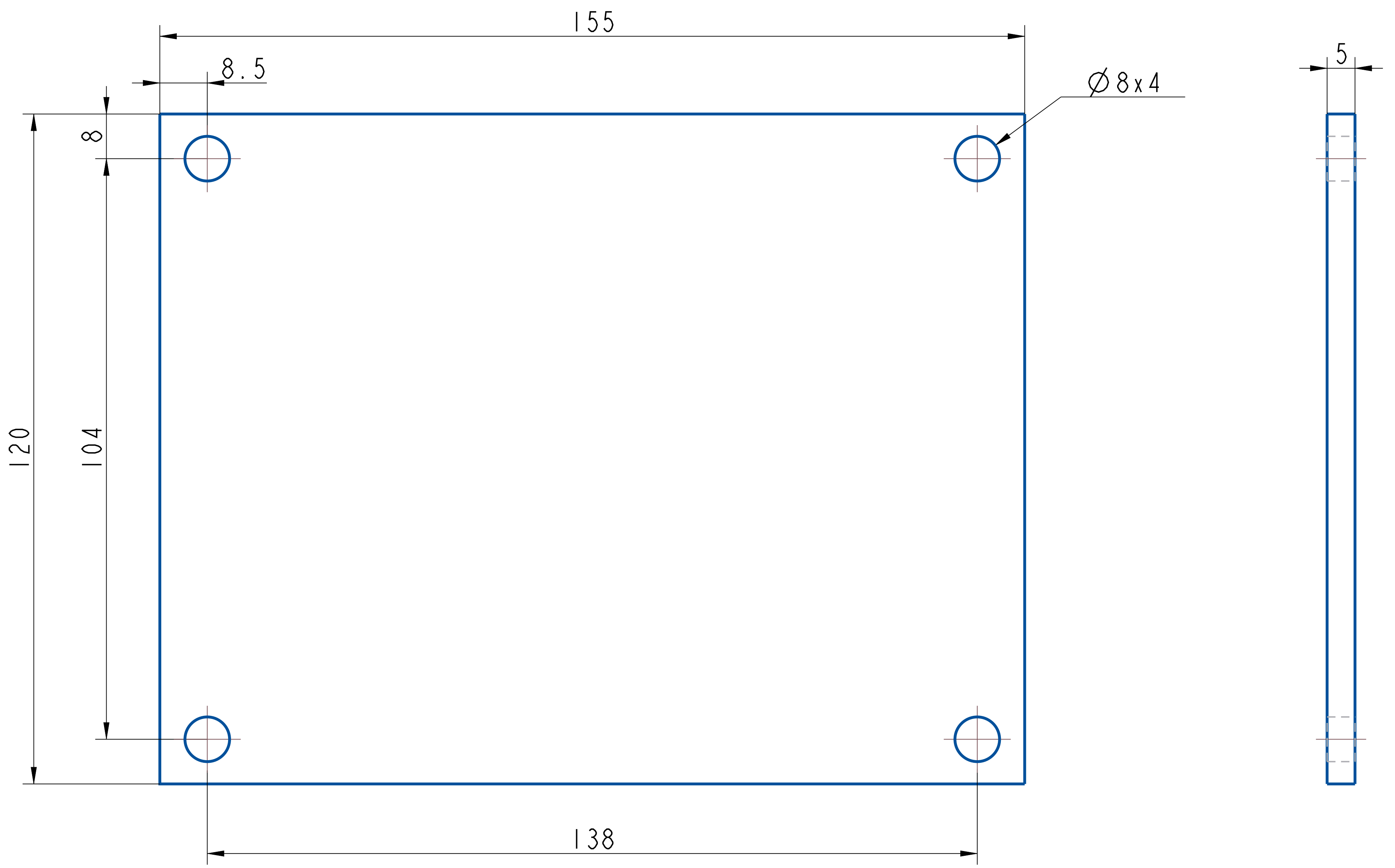


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

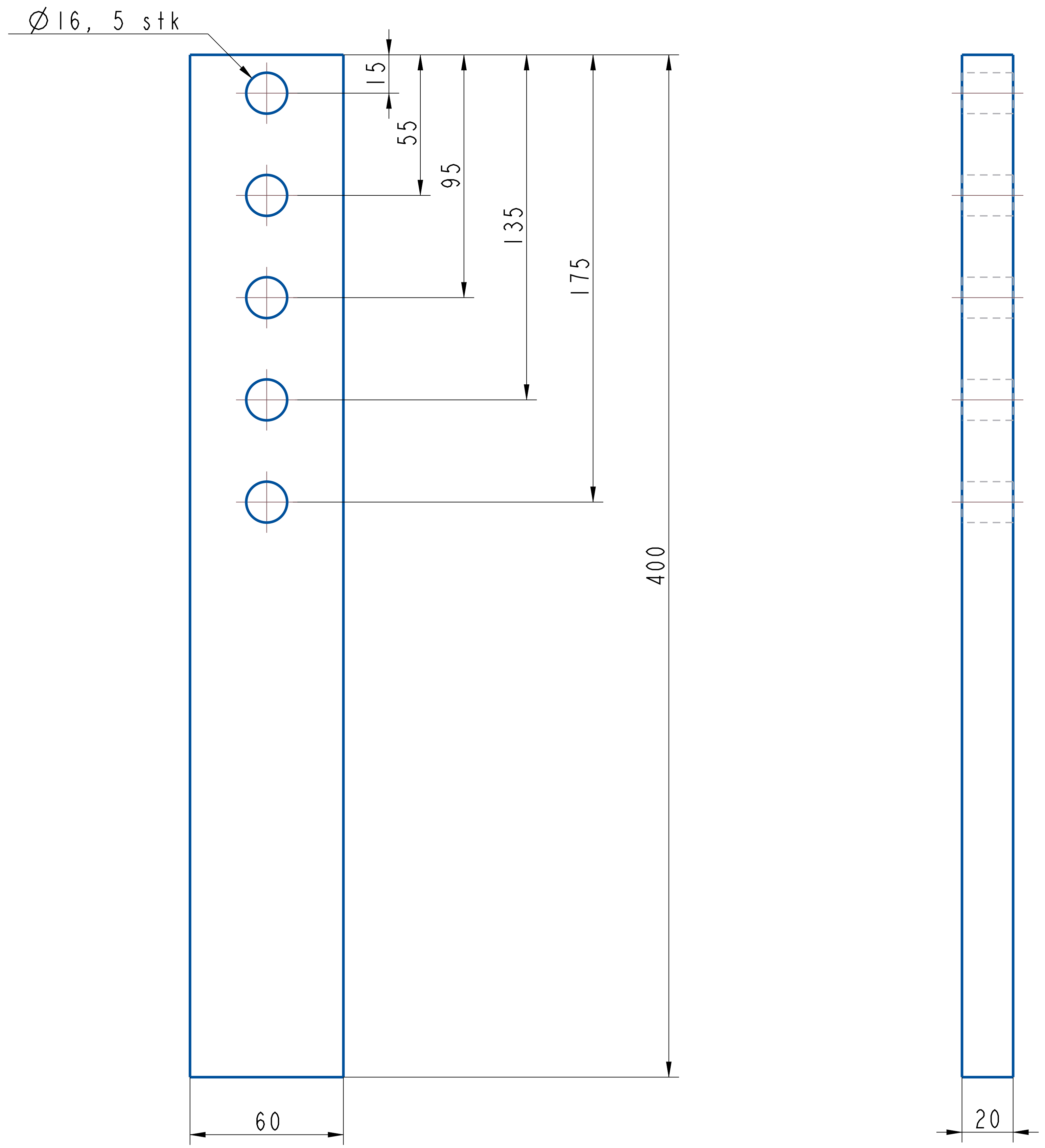
Konstr	Tegnet Eivind	Revisjon	Vekt	Skala 2:1	Format A3	Blad.nr 1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell FIRKANTROR_120X120_FESTEBRAKETT	Dato 19-Mar-20
	Beskrivelse FIRKANTROR_120X120_FESTEBRAKETT	Tegning



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
Konstr	Tegnet: Eivind	Revisjon	Vekt	Skala: 1:1	Format: A3 / Blad.nr: 1(1)
Høgskulen på Vestlandet IMM		Artikell/Modell: Firkantror_120x120x4_bunnplate			Dato: 19-Mar-20
		Beskrivelse			Tegning: FIRKANTROR_120X120X4_BUNNPLATE

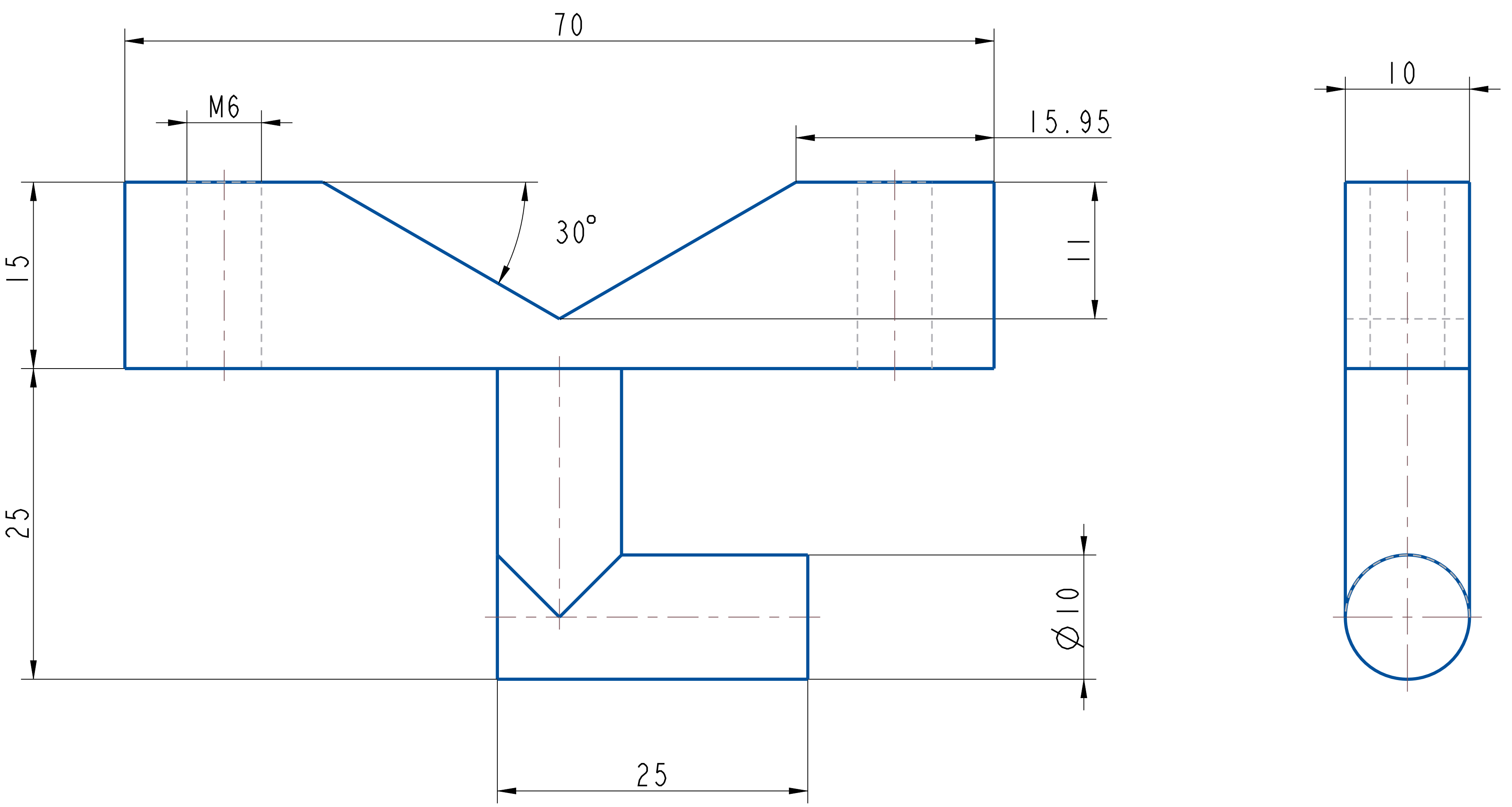


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:2	A3	1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell: FLATTJERN_STYRING_BAKKE	Dato: 19-Mar-20
	Beskrivelse:	Tegning: FLATTJERN_STYRING_BAKKE

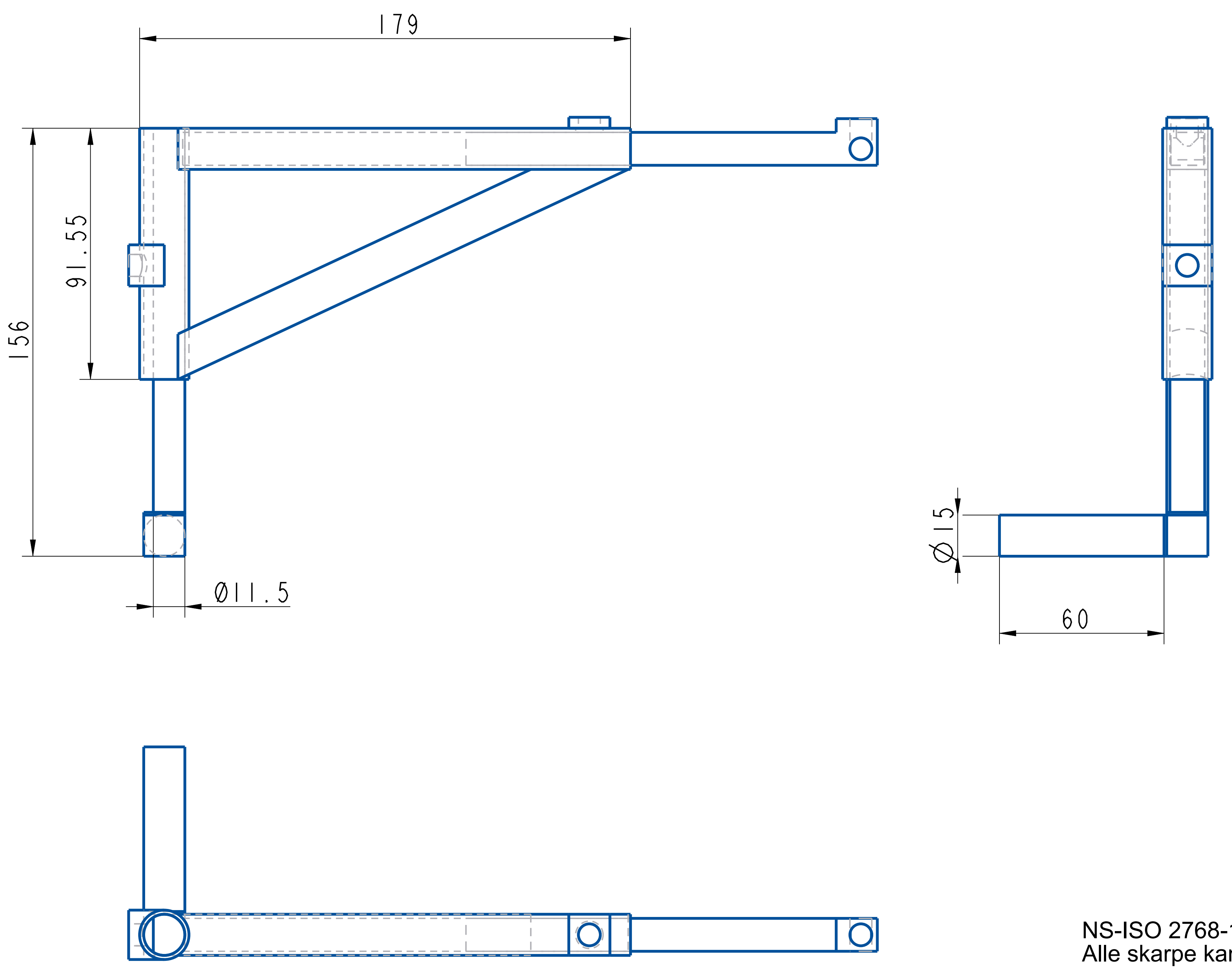


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			2:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: HOLDERTILPISTOL	Dato: 29-Apr-20
	Beskrivelse:	Tegning: GROV_HOLDER-TIL-PISTOL



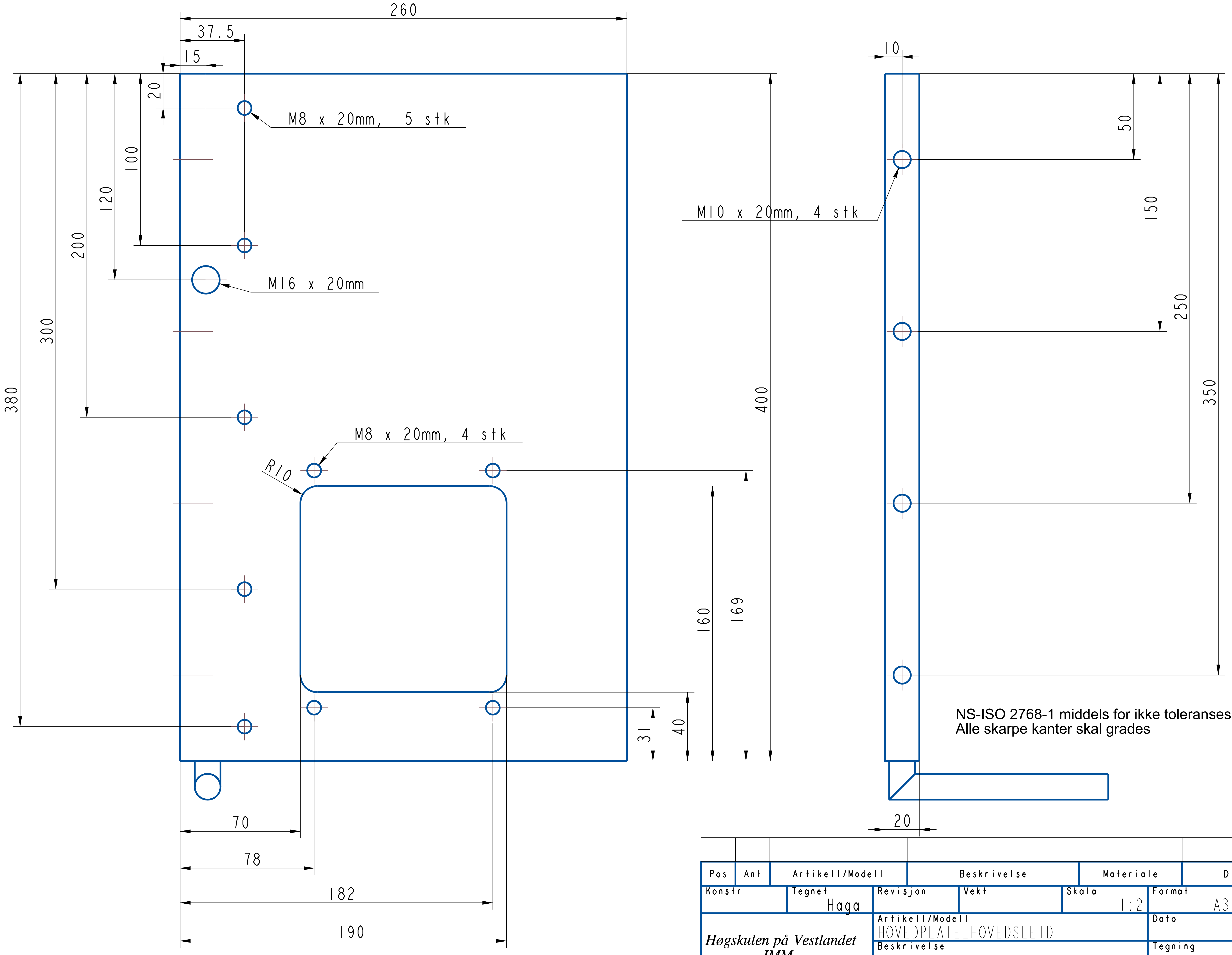
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
5	1	P_RULLER_SUB			
4	1	P_RULLER_STANGFESTE			
3	1	P_RULLER_STANG			
2	1	P_RULLER_GLIDESTYKKE			
1	1	P_RULLER_FESTEAKSLING			

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			1:2	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: P_RULLER
Beskrivelse:
Dato: 29-Apr-20
Tegning: GROV_RULLER



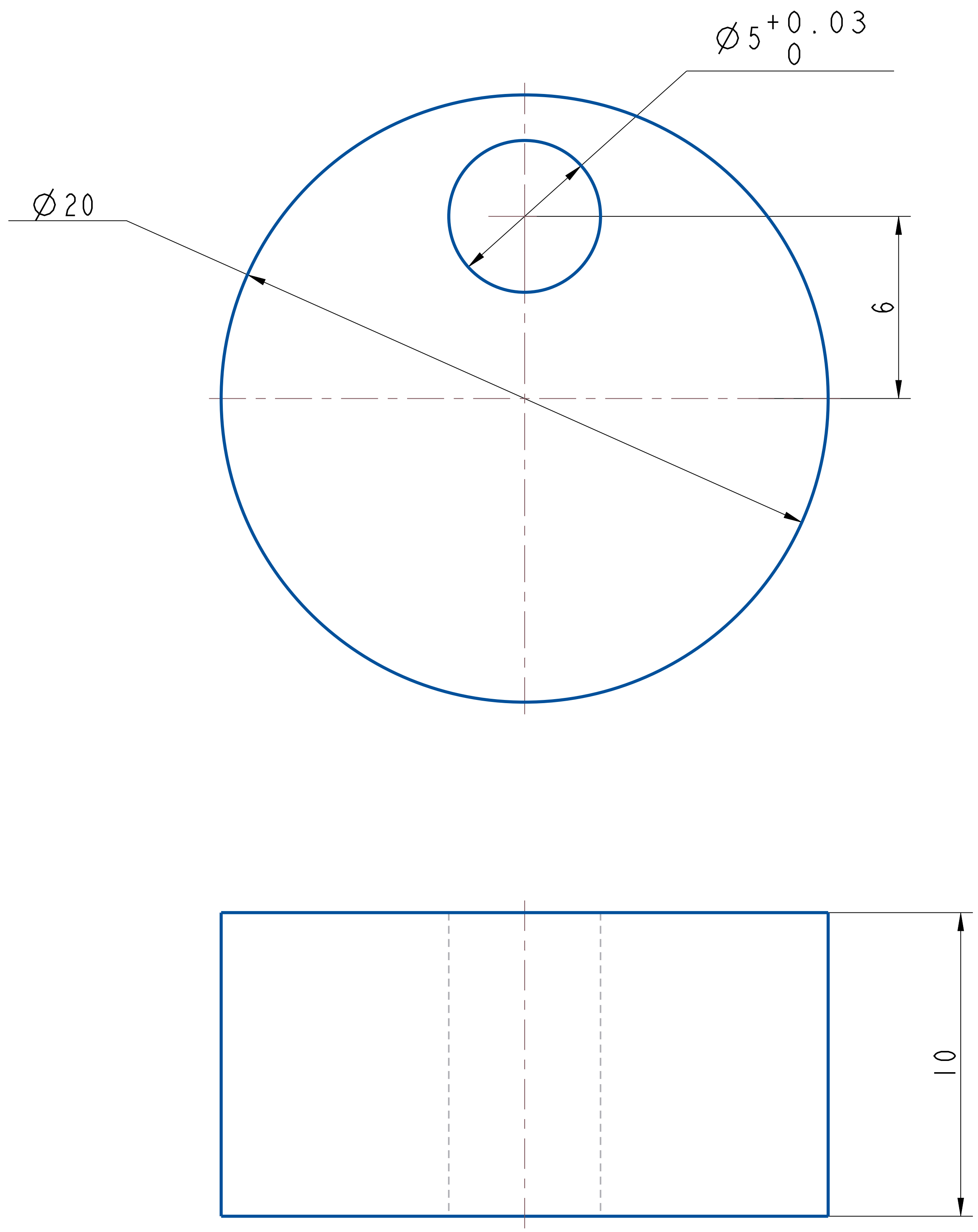
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

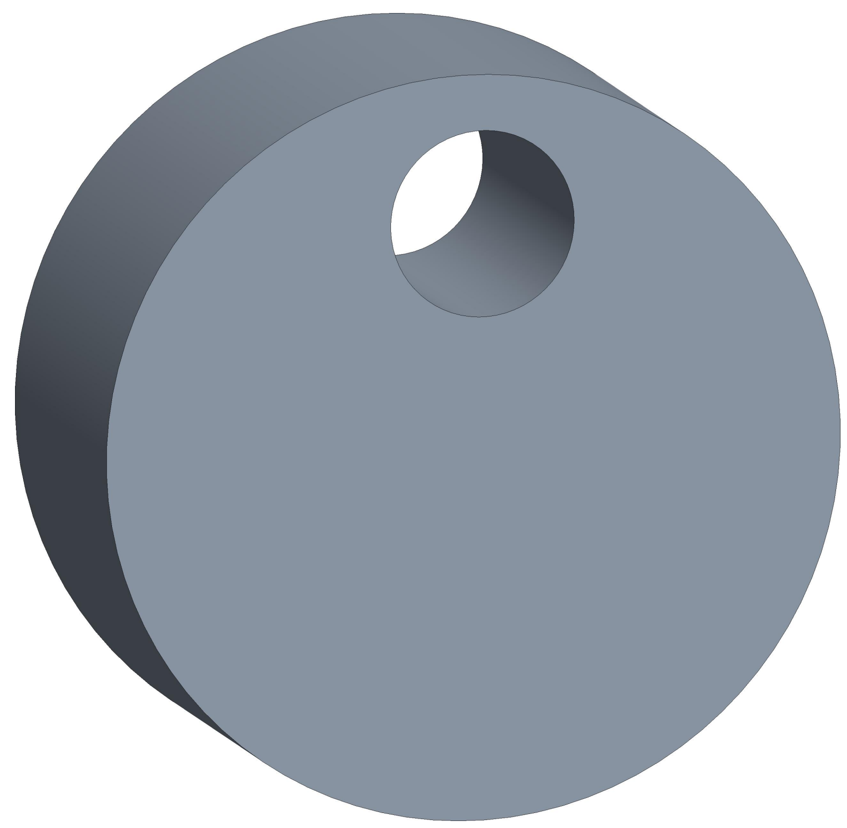
Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:2	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: HOVEDPLATE_HOVEDSLEID
Beskrivelse
Dato: 19-Mar-20
Tegning: HOVEDPLATE_HOVEDSLEID



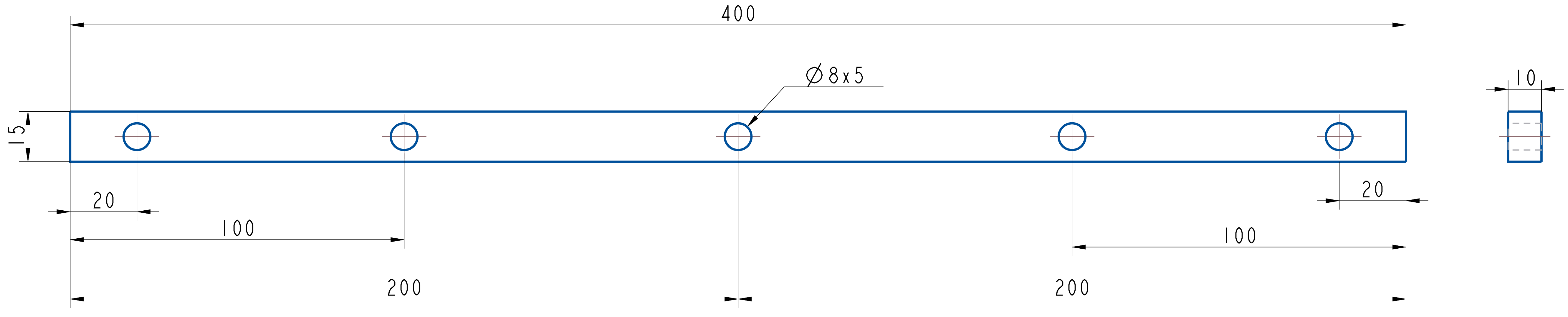


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Eivind			5:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: KAMSKIVE Beskrivelse:	Dato: 20-May-20 Tegning: KAMSKIVE



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Eivind			3:4	A3	1(1)

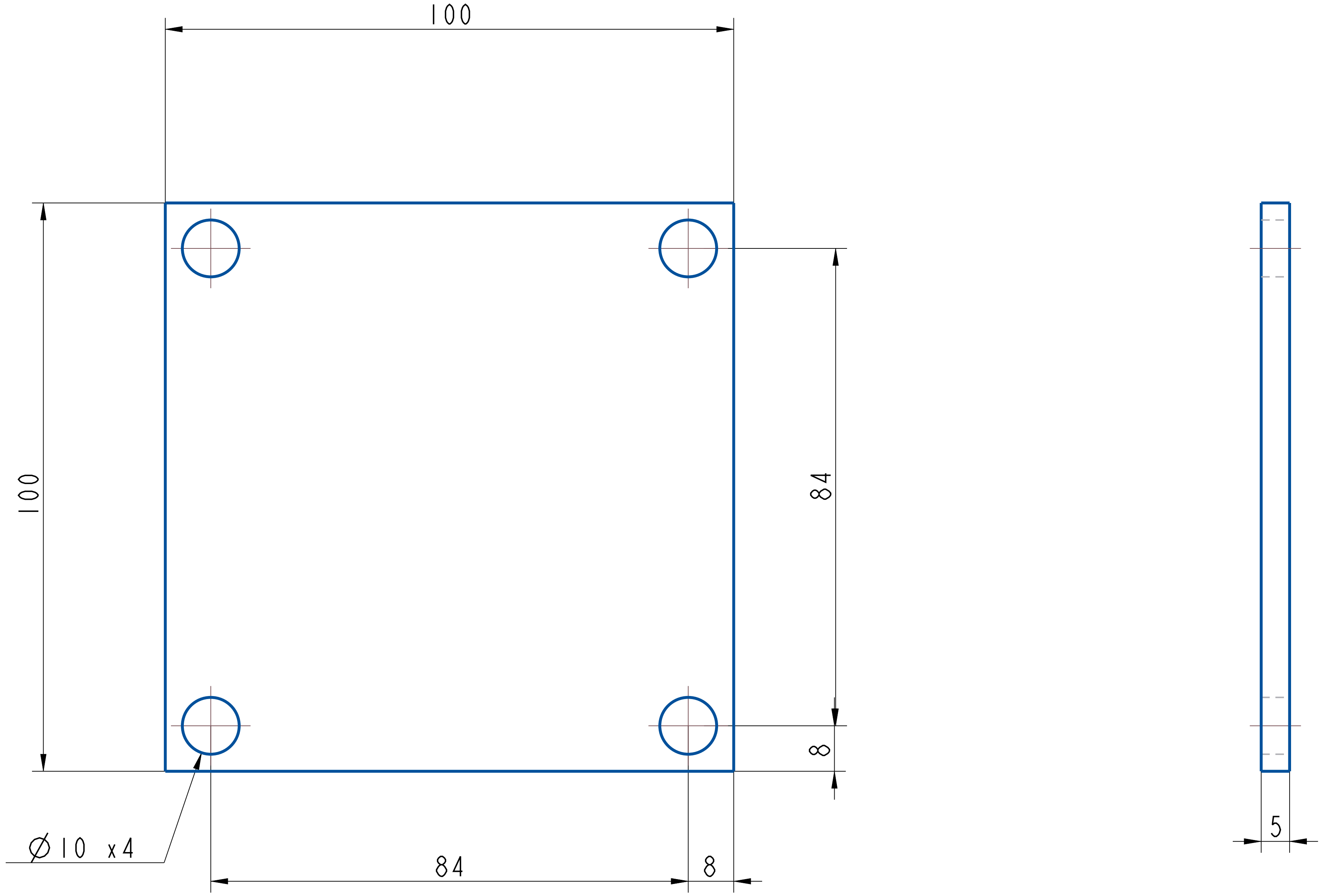
Høgskulen på Vestlandet
IMM

Artikell/Modell: L_SKINNE_INNSIDE

Beskrivelse:

Dato: 19-Mar-20

Tegning: L_SKINNE_INNSIDE

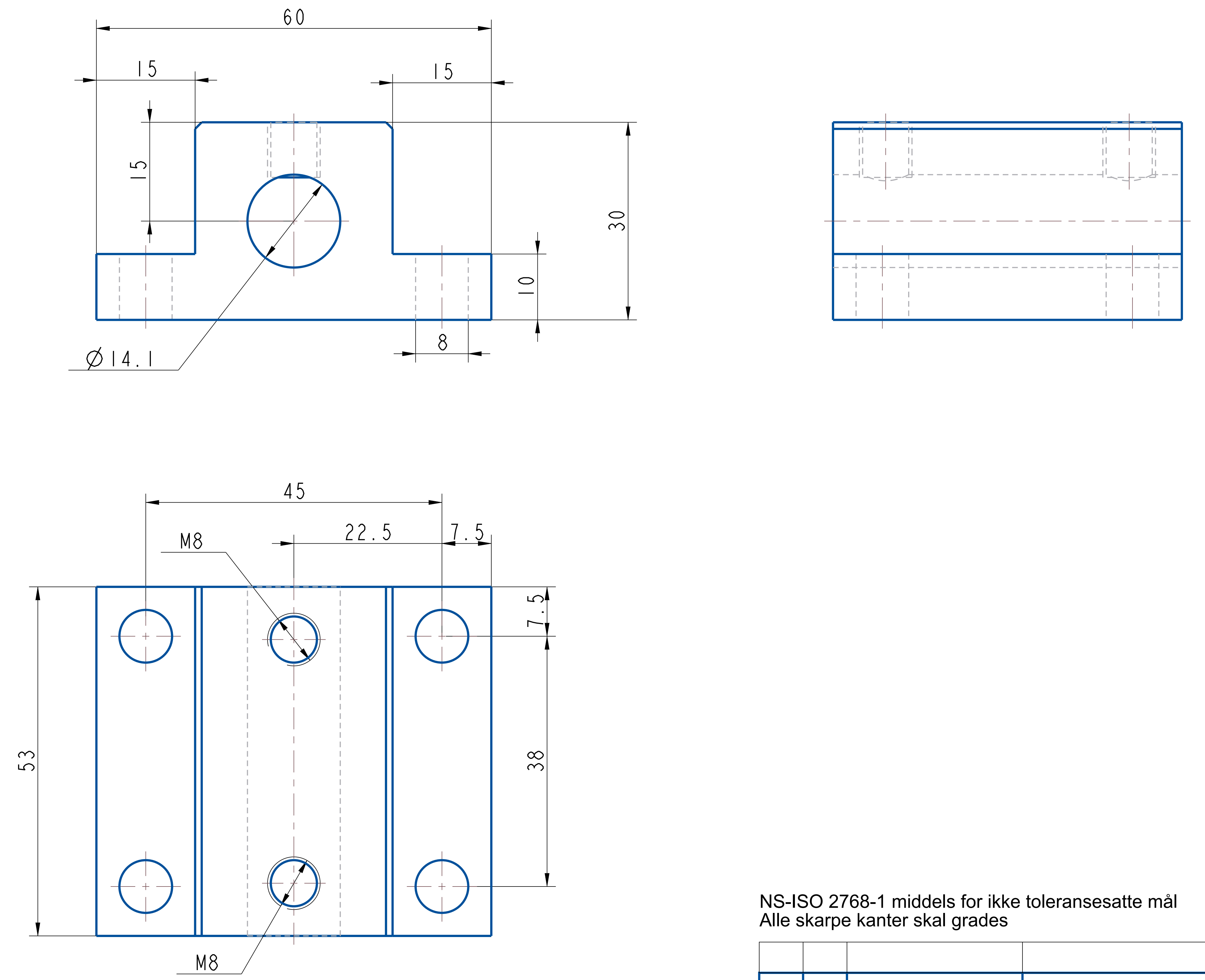


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:1	A3	1(1)

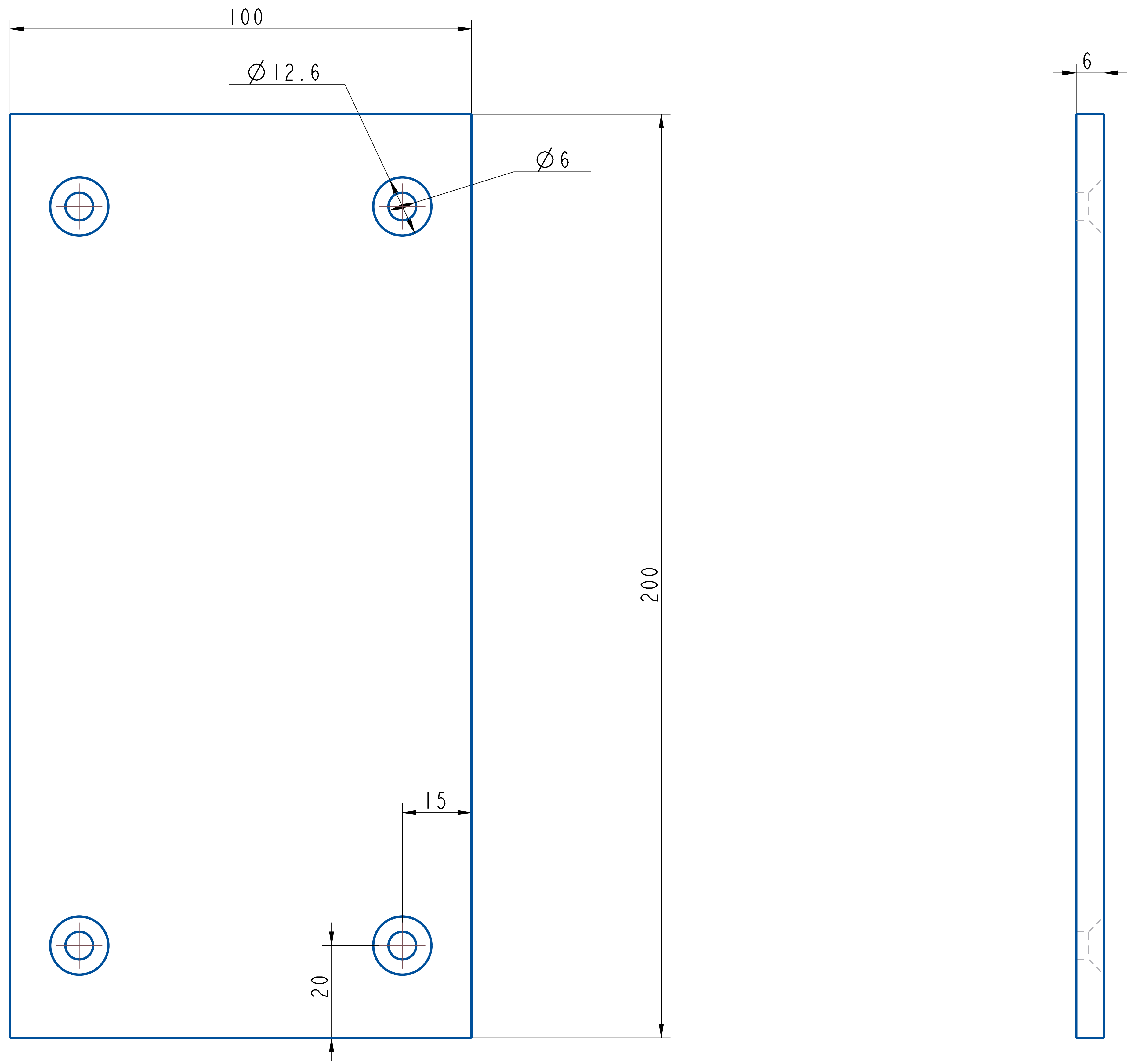
Høgskulen på Vestlandet IMM	Artikell/Modell P_BORD_FESTE_TIL_GULV	Dato 19-Mar-20
	Beskrivelse	Tegning P_BORD_FESTE_TIL_GULV



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon
				POM	

Konstr	Tegnet: Eivind	Revisjon	Vekt	Skala: 3:2	Format: A3
					Blad.nr: 1(1)
Høgskulen på Vestlandet IMM	Artikell/Modell: P_FESTE_TIL_LOCHNESS				Dato: 04-May-20
	Beskrivelse				Tegning: P_FESTE_TIL_LOCHNESS

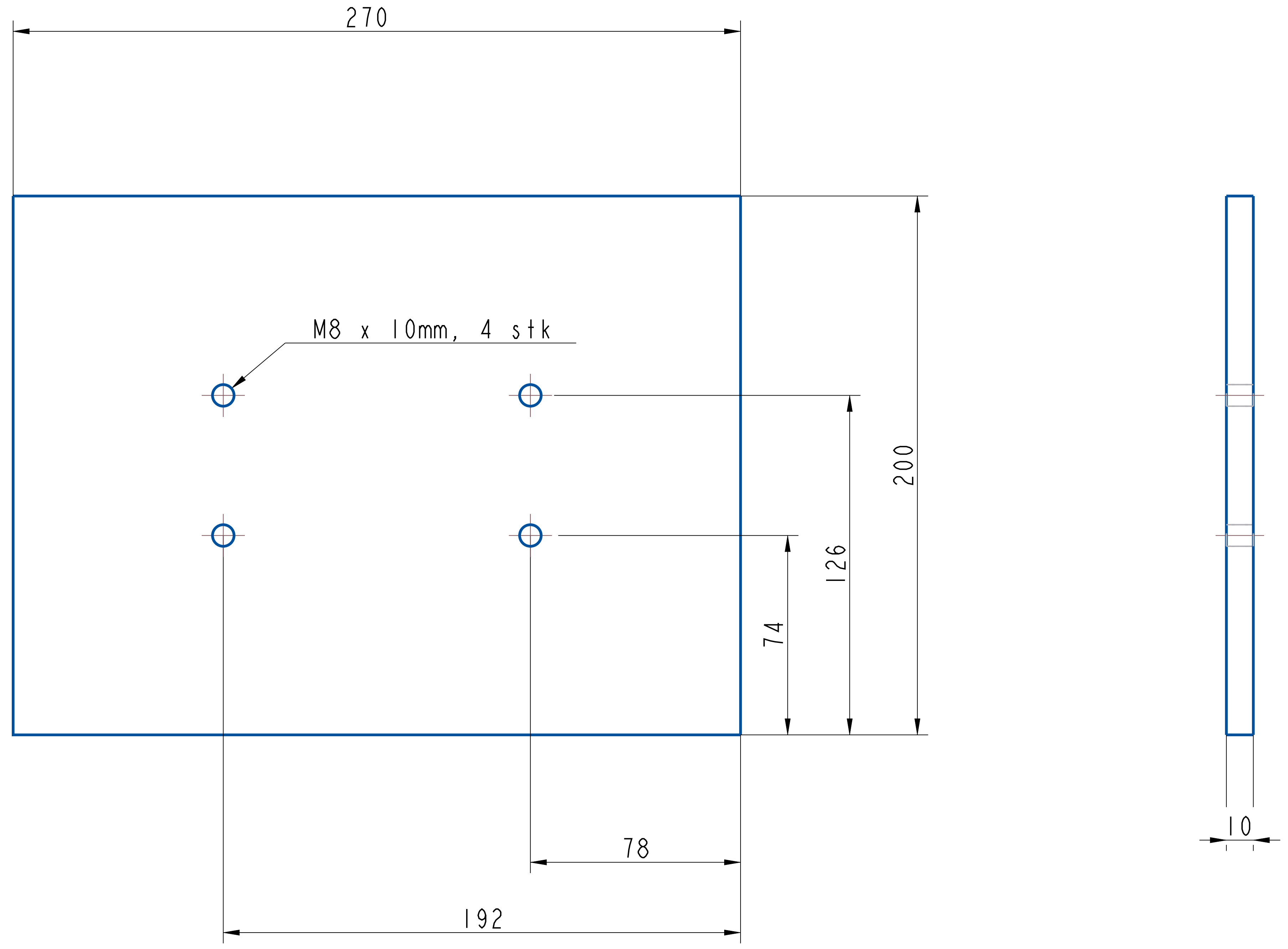


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell P_FIRKANTROR_FORING	Dato 04-May-20
	Beskrivelse	Tegning P_FIRKANTOR_FORING

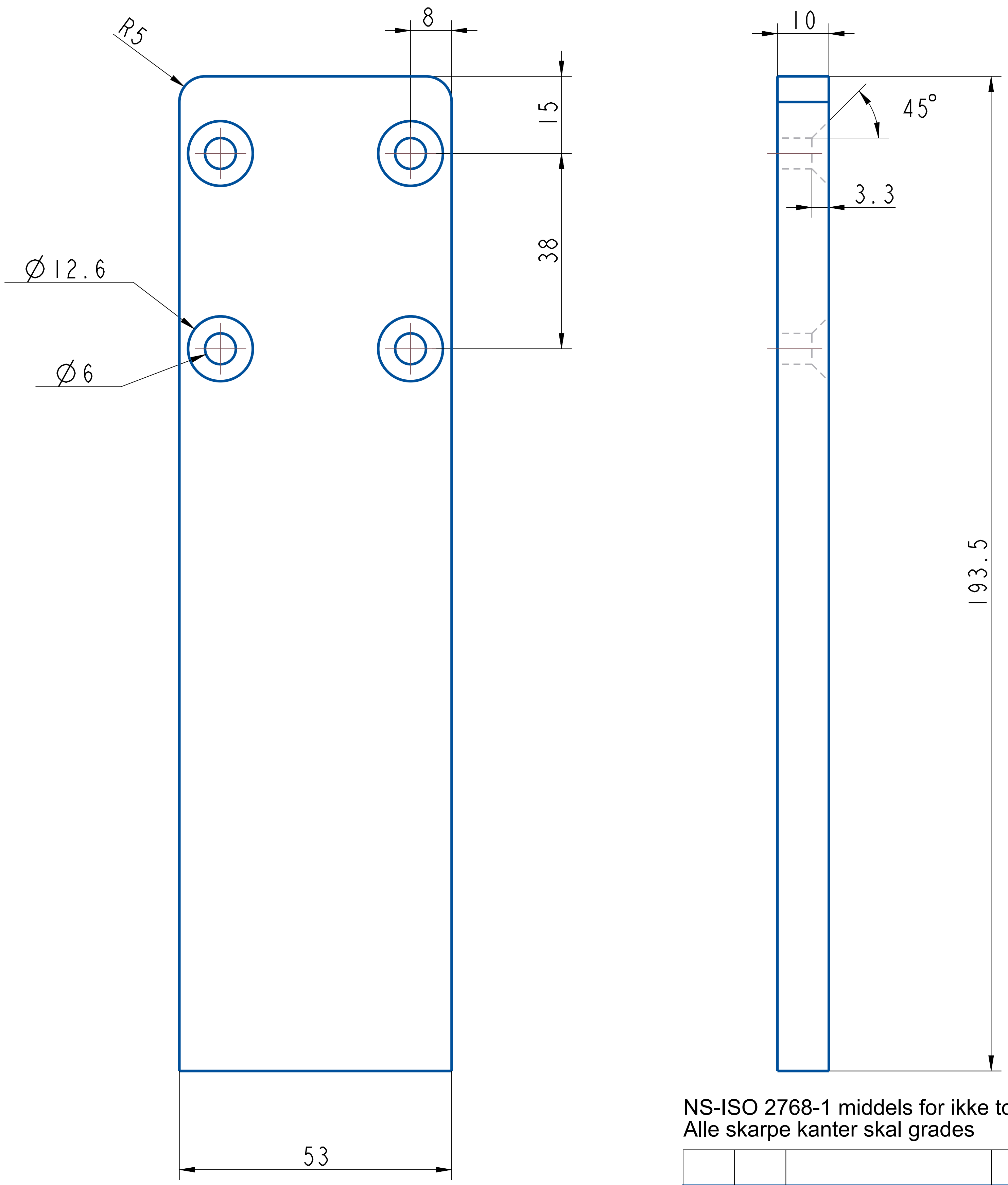


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:2	A3	1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell: P_FIRKANTROR_60X60_TOPPLATE	Dato: 19-Mar-20
	Beskrivelse	Tegning: P_FIRKANTROR_60X60_TOPPLATE



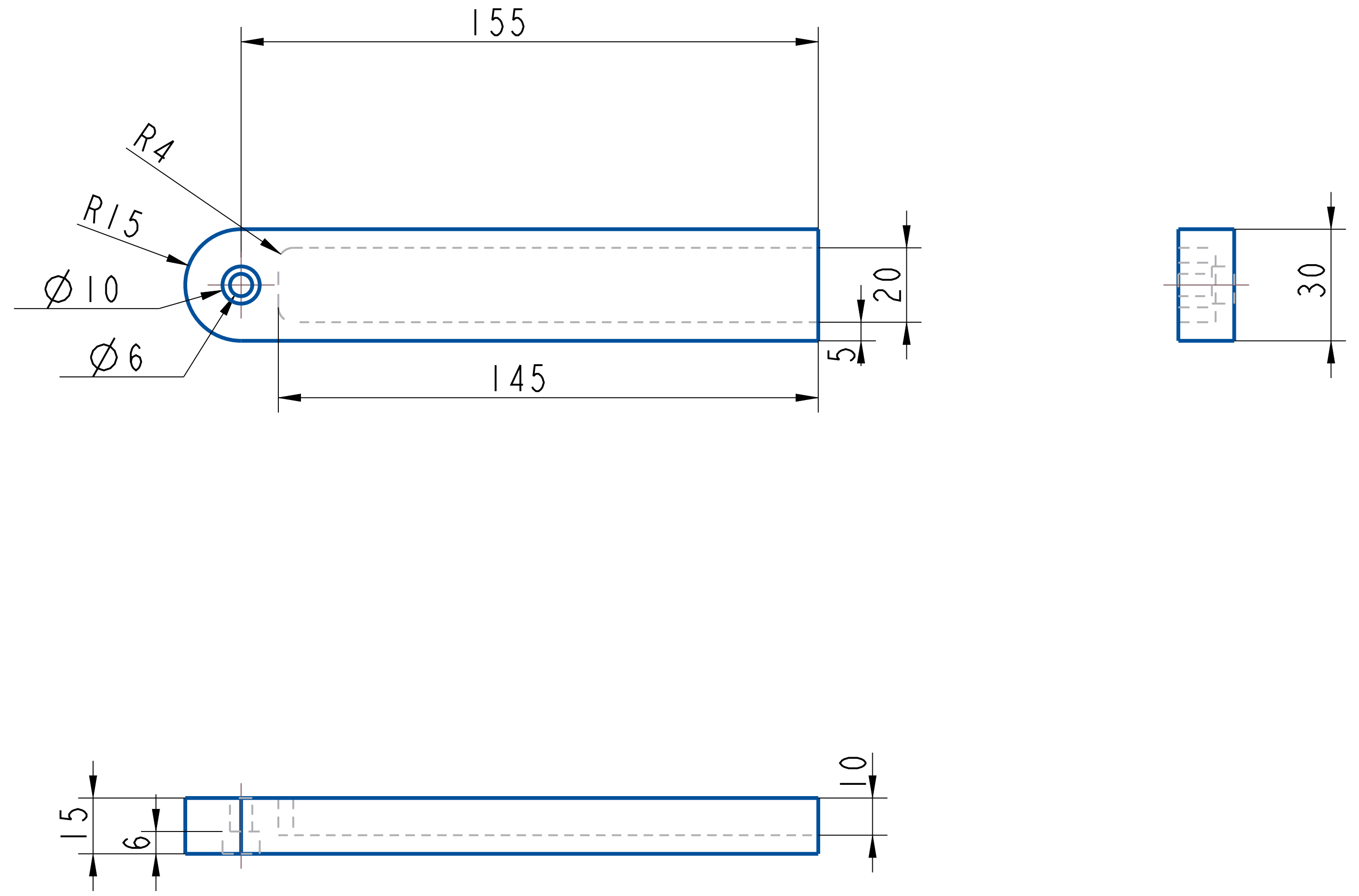
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			1:1	A3	1(1)

Høgskulen på Vestlandet
IMM

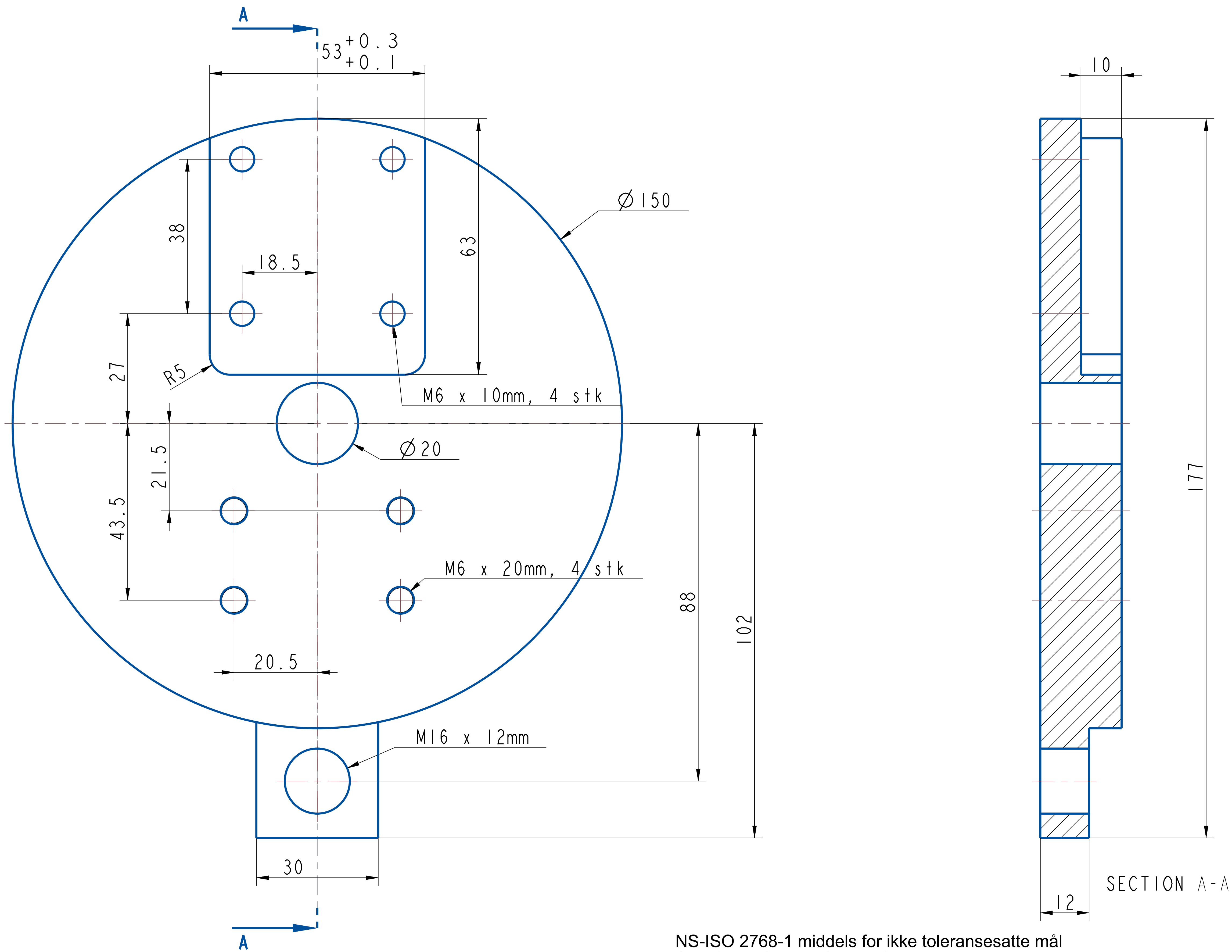
Artikell/Modell: P_PLATE_TIL_HUB
Beskrivelse:
Dato: 19-Mar-20
Tegning: P_PLATE_TIL_HUB



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet Nikolai	Revisjon	Vekt	Skala 1:2	Format A3	Blad.nr 1(1)
Høgskulen på Vestlandet IMM		Artikell/Modell P_ROTASJONS_ARM_DEL_A			Dato 19-Mar-20	
		Beskrivelse			Tegning P_ROTASJONS_ARM_DEL_A	



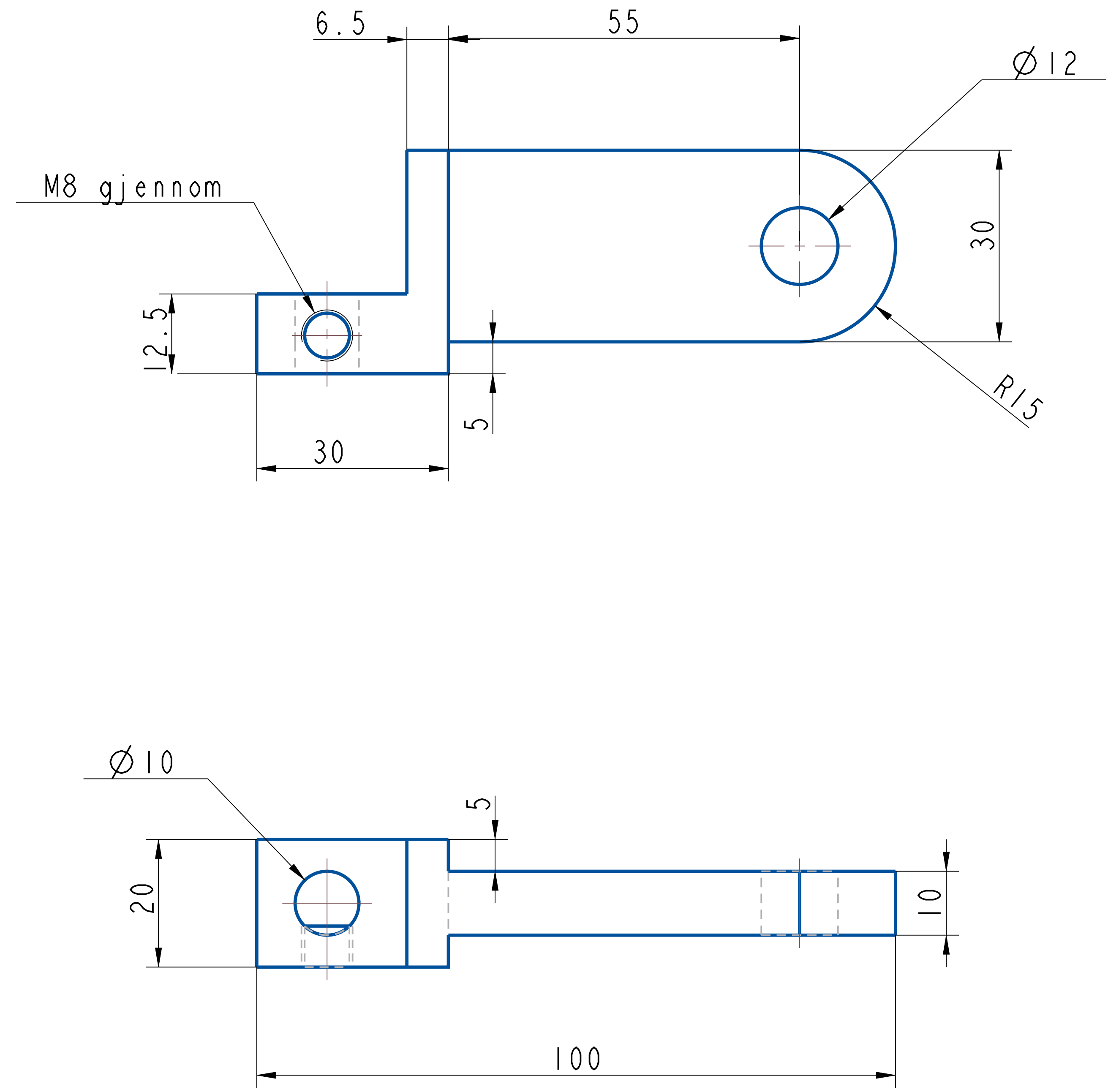
NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			1:1	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: P_ROTASJONS_HUB
Beskrivelse:
Dato: 19-Mar-20
Tegning: P_ROTASJONS_HUB

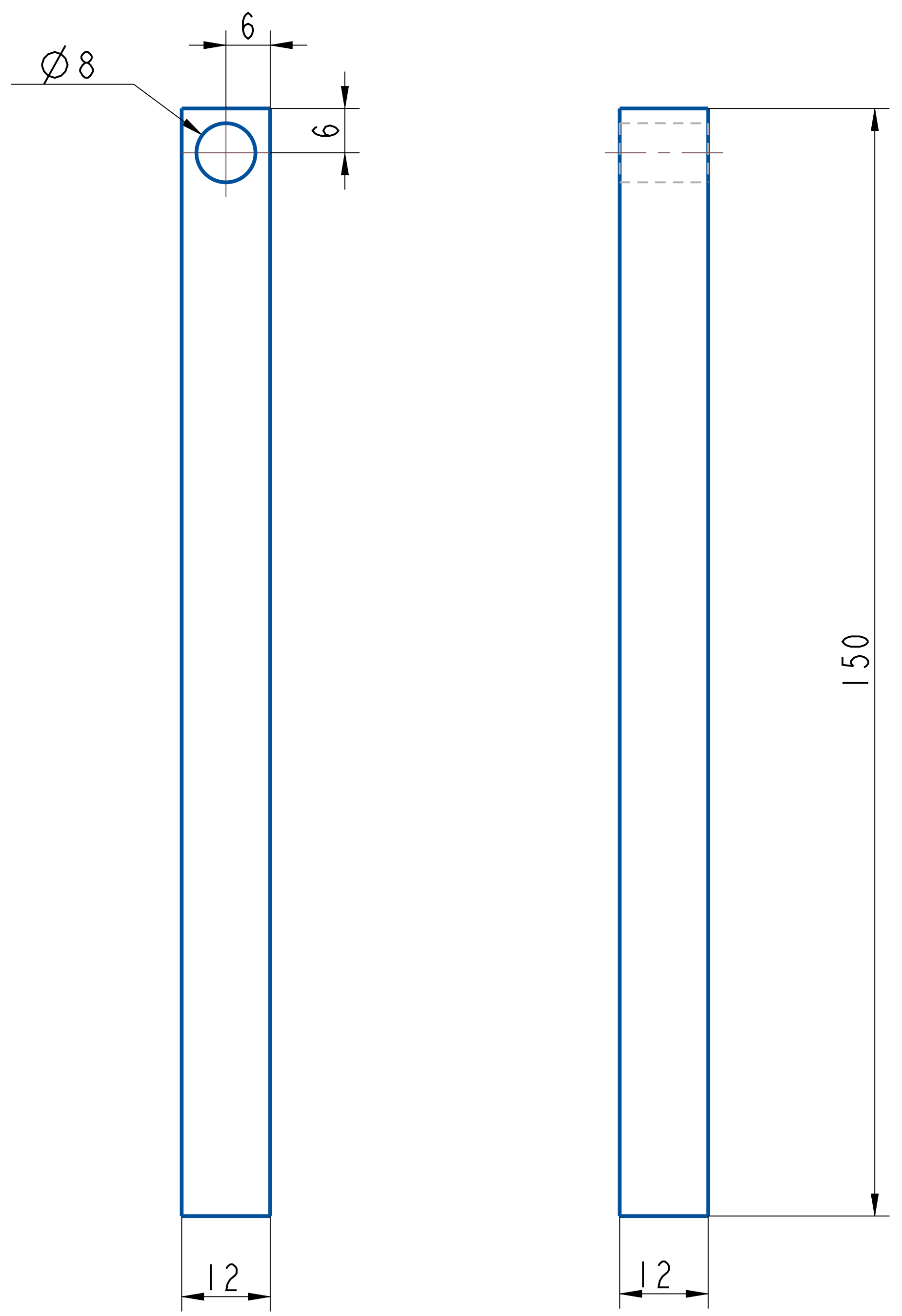


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			1:1	A3	1(1)

Høgskulen på Vestlandet *IMM*	Artikell/Modell P_ROTASJONSARM_DEL_C Beskrivelse	Dato 19-Mar-20 Tegning P_ROTASJONSARM_DEL_C

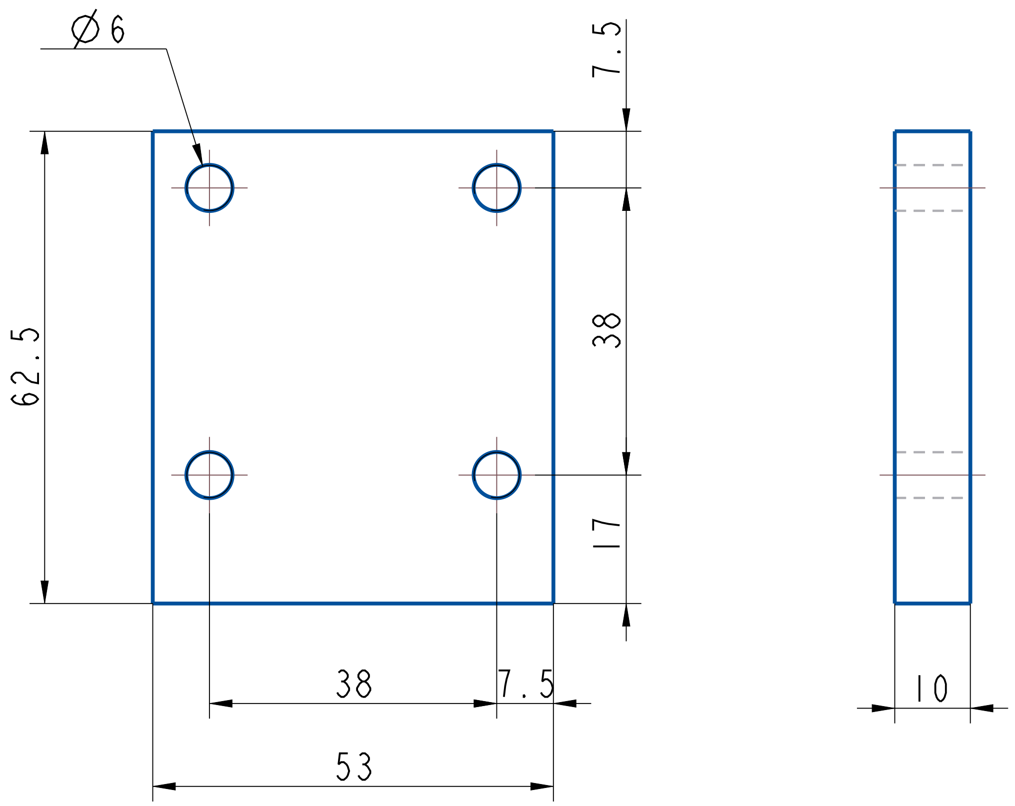


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			1:1	A3	1(1)

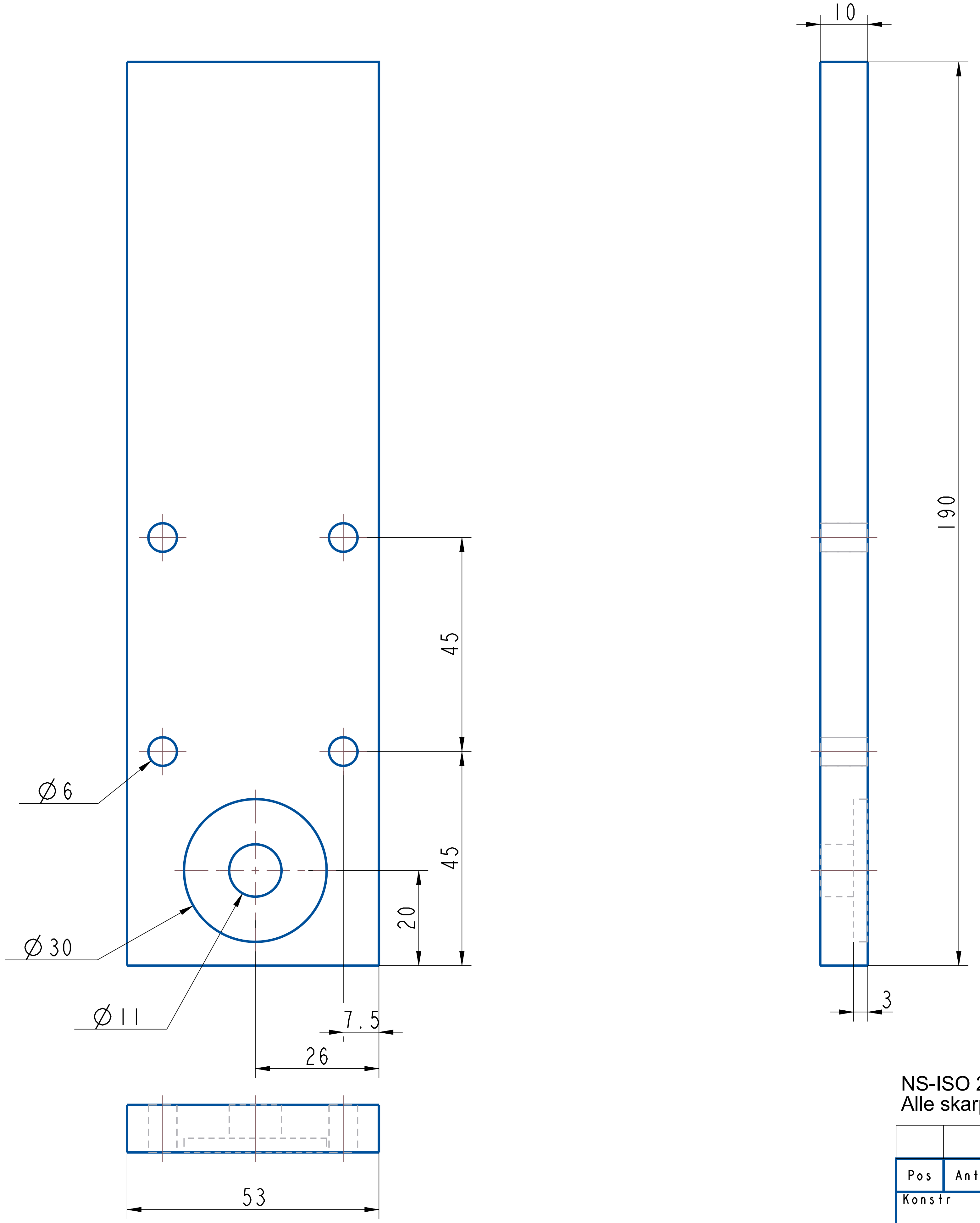
Høgskulen på Vestlandet IMM	Artikell/Modell: P_RULLER_GLIDESTYKKE	Dato: 19-Mar-20
	Beskrivelse:	Tegning: P_RULLER_GLIDESTYKKE



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet Nikolai	Revisjon	Vekt	Skala 1:1	Format A3	Blad.nr 1(1)
Høgskulen på Vestlandet IMM		Artikell/Modell P_VEGG_VIPPELATE			Dato 19-Mar-20	
		Beskrivelse			Tegning P_VEGG_VIPPEPLATE	

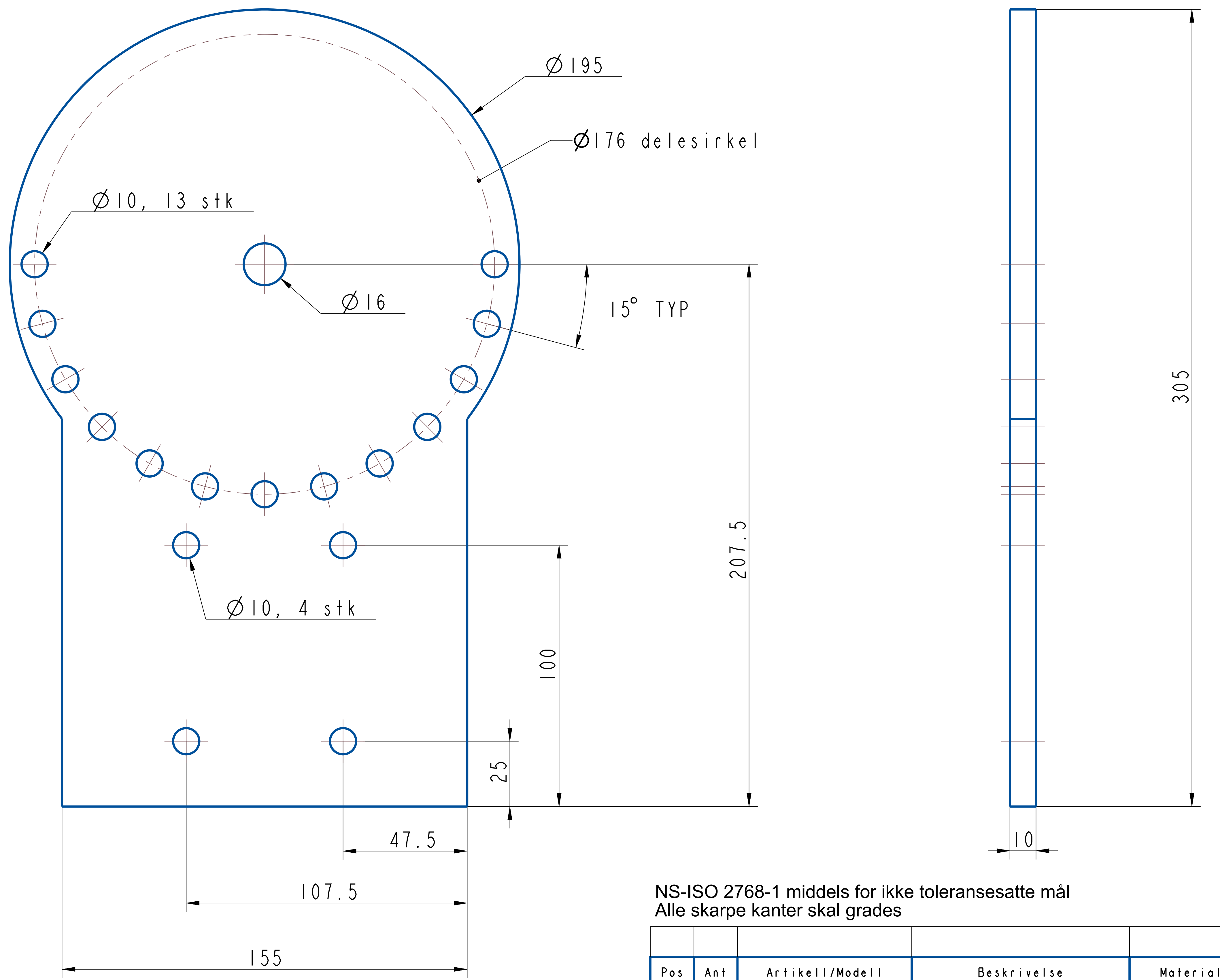


NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Nikolai			1:1	A3	1(1)

Høgskulen på Vestlandet IMM	Artikell/Modell: P_VIPPEPLATE_DEL_A	Dato: 19-Mar-20
	Beskrivelse	Tegning: P_VIPPEPLATE_DEL_A



NS-ISO 2768-1 middels for ikke toleransesatte mål
Alle skarpe kanter skal grades

Pos	Ant	Artikell/Modell	Beskrivelse	Materiale	Dimensjon

Konstr	Tegnet	Revisjon	Vekt	Skala	Format	Blad.nr
	Haga			3:5	A3	1(1)

Høgskulen på Vestlandet
IMM

Artikell/Modell: PLATE_PÅ_XY-SLEID
Beskrivelse:
Dato: 19-Mar-20
Tegning: PLATE_PÅ_XY-SLEID