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Master Thesis

Weld line quality monitoring of Sealing Elements using a newly designed test station

by

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Affidavit

I declare in lieu of oath, that I wrote this thesis and performed the associated research myself, using only literature cited in this volume.

Date

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Abstract

To be able to produce injection molded parts with uniform quality in a changing process environment process parameters have to be adjusted. Those process parameters are either fixed for a specific reason or can be adjusted in a certain range. The aim of this thesis was to investigate the influence of a changing switch-over point and the injection speed on the successful use of a movable mold insert system and the weld line quality of valve plates. The other factors in this injection molding process that could be considered to have an impact on the functionality and the produced weld line quality of this system were fixed.

To test the impact of those factors on the weld line quality a new test station was designed and manufactured. The test station is used to measure the weld line strength under bending load. It is capable of testing several types of valve plates in a quick and easy way. Two aspects were investigated during the testing. First, is the production process stable and second, can the injection speed be lowered and does the switch-over point influence the results. The process stability was examined by taking a look on shifts in weld line strength and changes in standard deviation over time. Even with a significantly changing mold temperature no significant trends or shifts could be found.

The weld line strength was tested by tracking force over displacement of the weld line area until failing. The results showed that once all movable mold inserts are triggered reliably there is almost no change in weld line strength detectable. However, some settings were tested in which the movable mold inserts did not work in the intended way. These settings showed an unsatisfactory weld line strength although all movable mold inserts were triggered. These settings produced parts but did not reliably trigger all mold inserts or showed crinkles at the surface markings of the movable mold inserts. These settings can be used as the low end settings for future testing but cannot be used for a production run.

Kurzfassung

Um eine gleichbleibende Produktqualität in einem Spritzgießprozess mit sich ändernden Voraussetzungen gewährleisten zu können, müssen Prozessparameter angepasst werden. Diese Prozessparameter können aufgrund von spezifischen Randbedingungen unveränderbar sein oder in bestimmten Grenzen angepasst werden. Das Ziel dieser Arbeit war es, den Einfluss des Umschaltpunktes und der Einspritzgeschwindigkeit auf die erfolgreiche Verwendung eines beweglichen Spritzgießformeinsatzes und die Bindenahtfestigkeit an Ventilplatten zu untersuchen. Weitere Faktoren, welche die Funktionalität dieses Systems und damit die Bindenahtfestigkeit beeinflussen könnten, wurden jedoch nicht variiert.

Um den Einfluss dieser Faktoren auf die Bindenahtfestigkeit überprüfen zu können, wurde ein neuer Prüfstand konstruiert und gebaut. Mit diesem Testgerät wird die Bindenahtfestigkeit durch eine Biegebeanspruchung der Bindenaht getestet. Mit diesem Prüfstand können mehrere verschieden Typen von Ventilplatten schnell und einfach getestet werden. Während der Tests wurde einerseits darauf eingegangen, ob der zu überprüfende Prozess stabil ist und andererseits ob die Einspritzgeschwindigkeit verringert werden kann sowie weiters ob der Umschaltpunkt die Ergebnisse beeinflusst. Die Prozessstabilität wurde mit Hilfe einer Untersuchung auf Verschiebungen und Trends in den Bindenahtfestigkeiten und der Standardabweichung über die Zeit untersucht. Trotz einer signifikanten Temperaturänderung der Spritzgussform konnten keine signifikanten Verschiebungen oder Trends festgestellt werden.

Um die Bindenahtfestigkeit zu überprüfen, wurde die aufgewendete Kraft und die korrespondierende Auslenkung bis zum Bruch aufgenommen und ausgewertet. Die Ergebnisse zeigten, dass sobald alle beweglichen Spritzgussformeinsätze verlässlich aus der Kavität geschoben wurden, keine Änderung in der Bindenahtfestigkeit mehr festzustellen ist. Es gab jedoch Einstellungen, bei denen zwar letztlich alle beweglichen Einsätze ausgelöst wurden, dies jedoch nicht kontinuierlich und zuverlässig. Dies führte in Folge zu nicht zufriedenstellenden Bindenahtfestigkeiten. Bei der Untersuchung dieser Bauteile konnte eine aufgeworfene, faltige Oberfläche an den Stellen der beweglichen Einsätze festgestellt werden. Diese Einstellungen können daher nicht zur Produktion von Gutteilen verwendet werden, jedoch können sie als untere Grenze für zukünftige Tests dienen.

ACKNOWLEDGEMENT

First of all, I want to thank the Montanuniversität Leoben and Hoerbiger Holding AG for the opportunity to conduct my master thesis in this interesting field of research which connected injection molding, material testing and test rig design. I especially want to thank my supervisor Dr. Marian Janko for his extraordinary help throughout all of my scientific development. Without him my path would surely have taken a different direction. Also I want to thank my supervisor assoz.Prof Dipl.-Ing. Dr.mont. Thomas Lucyshyn for his excellent support and help during the thesis.

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Contents

1. Introduction

As new, more efficient reciprocating compressors are developed and designed the need for better performing valves and therefore its main part, the sealing element, arises. The sealing element is the key factor for a valve's performance, efficiency and lifetime. Before research for a new type of sealing element had begun, the sealing element also known as valve plate was produced out of injection molded (IM) full disks using short fiber reinforced (SFR) high-performance thermoplastics. By now, the new sealing element design results in more complex semi-finished designs of injection molded parts. Because of this development less rework than with full disks is needed but the requirements on part design, material and geometrical precision raise new challenges especially in terms of design flaws and the IM process. Janko [31] developed new applicable designs for semi-finished sealing elements with a special focus on thermal expansion, warpage and improvement of weld lines. The new semi-finished sealing elements feature molded-in gates for the compressed medium to pass through. Therefore multiple weld lines can not be avoided. However, the weld lines as a weak spot reduce the integrity and therefore the lifetime of the molded component. For this reason, a new concept was developed to strengthen weld lines [31]. One developed key mold feature was a passive weld line modification system. The functionality of this system is presented more detailed in Chapter 2.6.2.

During previous studies [31] a process window for the production of each sealing element was defined with a focus on minimum warpage and reliability of the weld line modification system. As the weld lines are still the weakest part of the valve plate design it is suggested to set the weld line strength as a key parameter for good parts in the molding process. For this reason a lot of testing was performed under laboratory conditions on a Zwick Roell Z010 tensile test machine with a multi-purpose weld line fixture which allows to test similarly to a three-point bending test. The results of these tests were conclusive and reproducible but slow and time consuming.

The objective of this thesis was to develop, design and build a new test station for quick and easy testing of the produced valve plates directly at the shop floor. It should be as easy and reliable as possible so machine operators could use it with minimum enrollment to produce reliable data. In advance the test rig will be used to find the process window for parts of sufficient quality with the focus on weld line strength in addition to minimum warpage and reliability of the weld line modification system. To achieve that, the process window from earlier tests will be used.

2. State of the Art and Theoretical Background

This chapter outlines the function of valve plates as sealing elements in compression technology. On this basis a brief look on the injection molding process is taken and the used materials, the factors for the quality of weld lines and the basics for the design of a test rig for valve plates are discussed.

2.1. Valve Plates used in Reciprocation Compressors

This subsection contains a short introduction into how reciprocating compressors work, how valves are used in those compressors, the task valve plates perform in those valves as much as their geometry and how they work.

Industrial reciprocating compressors are widely used in the oil and gas industry, chemical industry, cooling, refrigeration plants and many more. Figure 1 shows a compressor without the motor, drives or piping. The working principle is much like a reversed rail road steam engine. The motor powers the piston which compresses gas in a double-action movement meaning both moving directions compress the medium.
During the back movement of the piston the volume in one of the two compression chambers expands. The gas e.g. air is therefore sucked into the chamber through opened feed valves. The discharge valves are closed meanwhile. As the piston reverses its movement the feed valves seal the chamber and compression begins. During compression the discharge valves are opened for the compressed gas to leave the compression chamber.

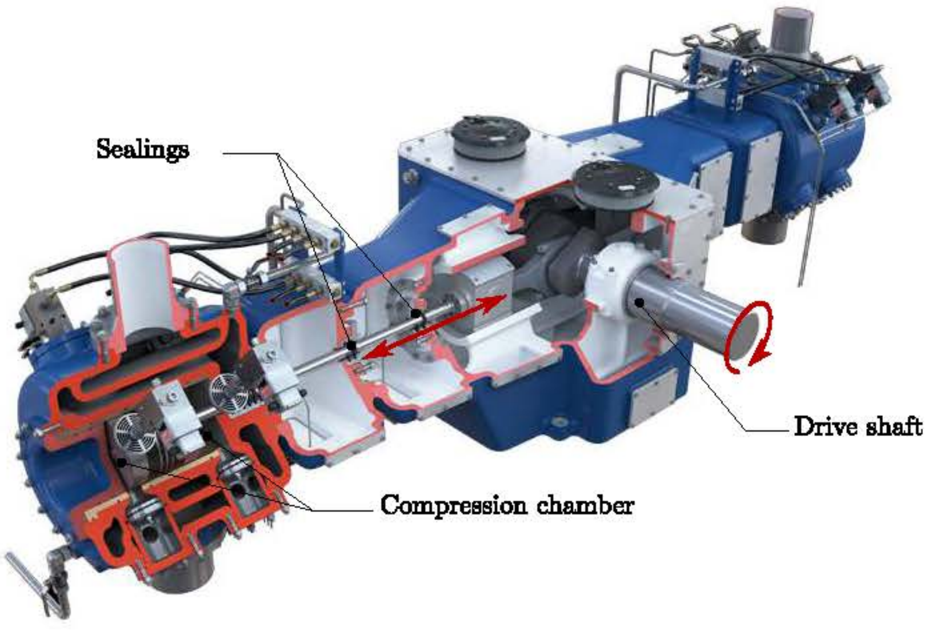


Figure 1: Cut section of a reciprocating compressor. [30]

Key components of this compression process are the valves that charge and discharge gas into and out of the compression chambers of the compressor. A basic design valve consists of four main components (Figure 2):

- *Sealing element*: The sealing element prevents the gas from escaping the compression chamber in an uncontrolled way. It is pushed against the valve seat by valve springs. The valve springs are arranged symmetrically across the whole valve plate geometry.
- *Valve guard with valve springs*: The valve guard houses the valve springs. The valve guard of charging valves is the element that is mounted directly to the compression chamber. The valve guard for discharge valves is the last part of the valve for the compressed gas to pass.
- *Valve seat*: The valve springs push the valve plate against the valve seat. The valve plate and the valve seat touch and therefore seal on their precisely manufactured edges.
- *Unloader with unloader pins and unloader spring*: If the valve is used to control the feed volume of the compressor the sealing element has to be pushed back towards the valve guard in order to unseal and open a passage for the compressed gas. This action is performed by the unloader. The unloader with its unloader pins is controlled by the control system to control the output volume of compressors. The unloader spring holds the unloader away from the sealing element when the system is deactivated.

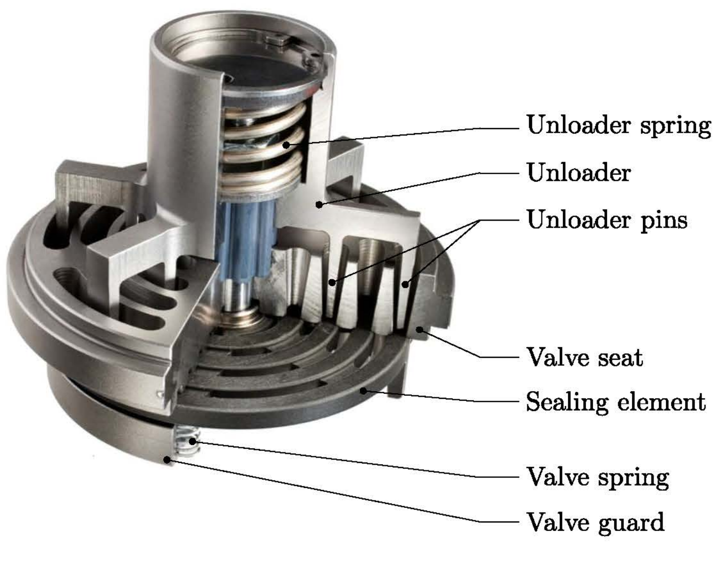


Figure 2: Cut section of a valve for a reciprocating compressor. [30]

The key component of every valve is the sealing element that seals off two areas with a different level of at least one certain characteristic. For example a bottle cap of a soda bottle seals off the inside volume of the bottle against the outside atmosphere in terms of pressure and fluid leakage. Therefore the cap is a sealing element.

The same principle can be used on valve plates as sealing elements in compressors (Figure 3 shows a semi-finished sealing element manufactured by Hoerbiger). The valve plate seals off the compression chamber against the feed and discharge lines. A semi-finished valve plate as shown in Figures 3 and 4 consists of multiple concentric rings that are connected by so called main and secondary webs. From now on, the outmost ring is referred to as ring 1 proceeding to the innermost ring named ring 8. On the edges of every ring a sealing edge is machined in order to fit precisely onto the valve seat to seal properly. In the center of the valve plate a guiding can be seen to prevent the plate from tilting. Between every two rings a passage can be found. During the feed or unload action of the compression chamber the medium flows through those passages. The critical spot is the area that is opened and closed by the sealing edges of the valve plate. The bigger those passages are the less pressure loss is achieved. To get more space between the valve plate sealing edges and the valve seat bigger diameters and more rings can be designed.
The geometry of the sealing edges is also crucial to the efficiency of the valve. A more detailed explanation about the sealing edge geometry can be found in [31].

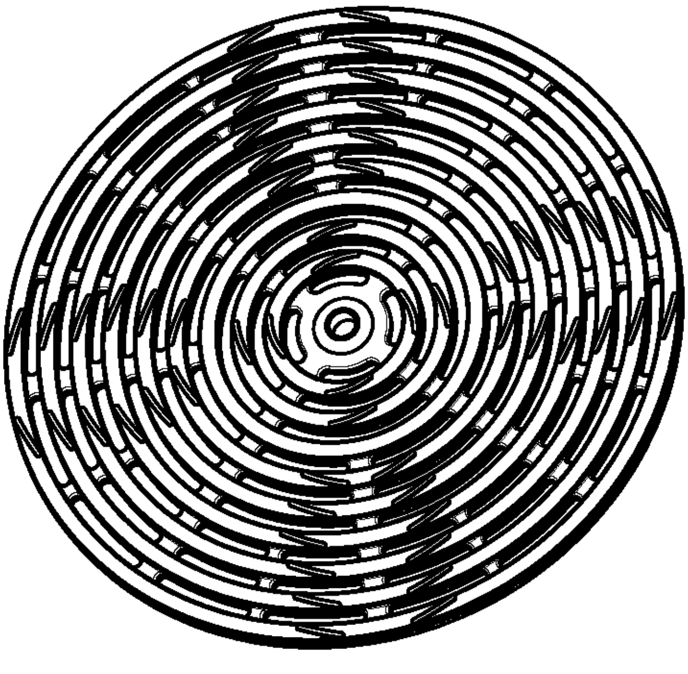


Figure 3: A semi-finished sealing element (261XP) 261 mm in diameter which was used for testing.

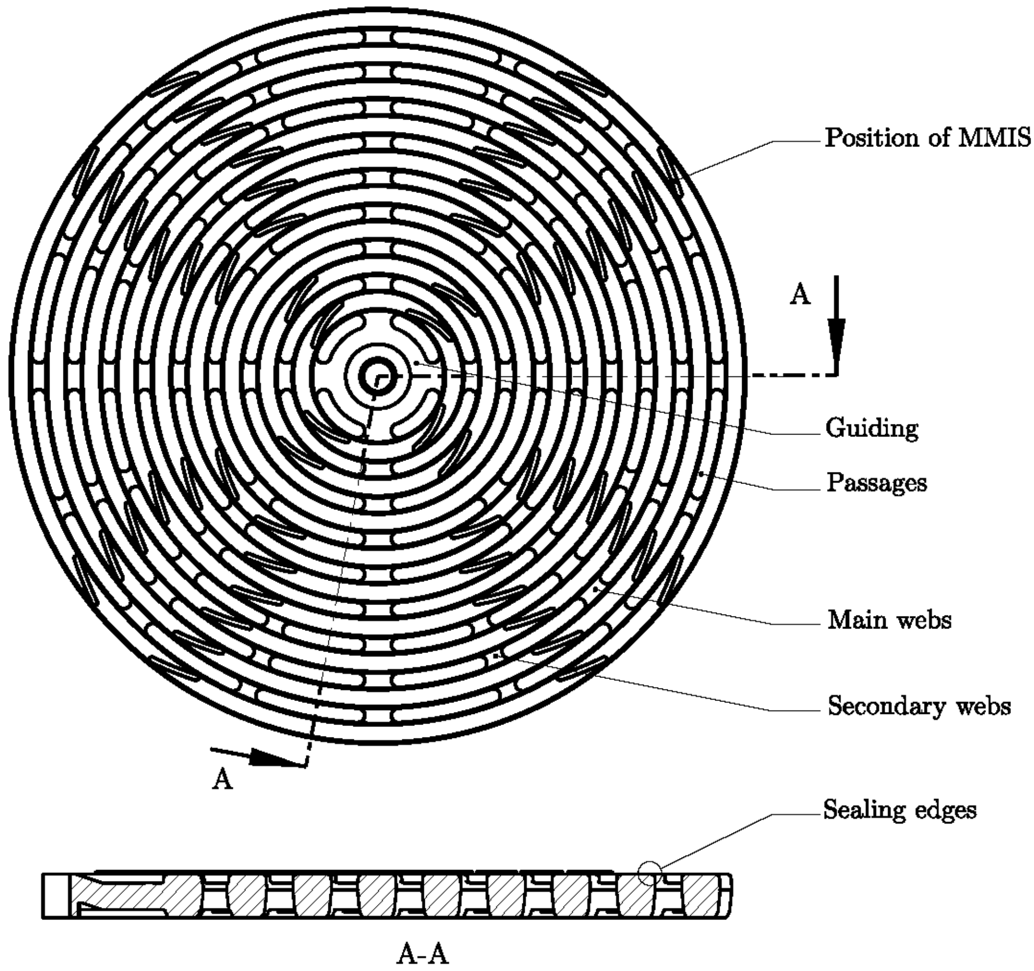


Figure 4: Down view and cut section of a semi-finished 261XP sealing element. MMIS stands for Movable Mold Insert System. A detailed explanation can be found in Chapter 2.6.2.

2.2. The Injection Molding Process

This subsection gives a very brief summary of the injection molding (IM) process that is used to produce the semi-finished sealing elements.

An injection molding cycle starts with the closing of the mold. The movement speed of the closing operation can be set on several speeds depending on the position of the moving plate of the injection molding machine. Shortly before the plates close the speed is reduced to a minimum to prevent mold and machine damage. After closing the set clamp force is applied. The clamp force ranges from a few 100 kN up to several 1000 kN. During the closing action the injection unit can be moved and pushed towards the mold in order to prevent molten material from escaping the gap between the nozzle of the injection unit and the mold. The applied forces typically range from 5 kN to 20 kN. As the next step, molten plastic is injected into the mold with a pressure of about 200 bar to 2000 bar. [16]

When the cavity is almost completely full (approx. 95 % to 98 %) the transition from injection pressure to packing or holding pressure is performed. The transition can be performed in three different ways:

- *Volume sensitive*: The transition depends on the position of the screw and therefore on the volume of the injected material. Because of the easy and save implementation this is the most common method.
- *Pressure sensitive*: When using this transition method the transition is performed when a certain injection pressure is reached during the injection process. This method shows very good results when pressure sensors are located in the mold and are used to trigger the switch-over. Using a pressure sensor located in the areas last to be filled show very good results and can help controlling the process. Of course implementing pressure sensors into the mold is expensive or sometimes impossible.
- *Time sensitive*: The transition is performed until a certain time has elapsed without considering injected volume or applied pressure. It is the easiest way of implementing a switch-over. However, it is not based on process parameters like pressure or volume and therefore is not affected by process changes like changes in material viscosity or temperature changes. This potentially results in under/overfed parts, sink marks etc.

It is very common to use volume dependent transition as the primary transition argument. However, if this argument fails, pressure and time dependent transition can be used as a second or third layer argument to prevent mold and machine damaging and ending the cycle to go into error mode.
During holding phase, pressure is applied to the plastic inside the cavity. Its main purpose is to prevent shrinkage as the plastic cools down and solidifies beginning at the cavity walls towards the thickest areas of the molded part. As long as the sprue has a molten core more material can be forced into the cavity to balance the volume loss of the solidification. The elapsed time starting from injection until the solidification of the sprue's core is called sealing time. After the sprue is completely solid no pressure and material can be transferred to the cavity. The molded part stays in the cavity for cooling until it reaches a certain level of rigidness and stiffness to be ejected after opening the mold.

2.3. Process Window

For every process certain parameters have to be adjusted to ensure proper function or production of goods. This set of parameters and their ranges are summarized as a so called process window. This chapter points out what a process window is and why it is important for a good process.

Do define a "good" process at least one key parameter must be selected (e.g. mass, length etc.). A set value is now assigned to the key parameter (e.g. mass or length). The laws of nature state that this set values can only be reached with a certain deviation due to random scattering. Therefore tolerances are defined. A tolerance defines how much a manufactured key parameter is allowed to deviate from its specified value. In a perfectly stable and controlled process the deviations of the manufactured products will result in a Gaussean bell curve with its maximum at the set value. In reality during manufacturing even if the process was perfectly controlled in the beginning, at some point it will shift because of material changes, wear, temperature changes etc. For this reason the process has to be adjusted to meet the tolerance specifications again. To adjust a process, specifically an injection molding process, a variety of machine parameters can be adjusted. However, a lot of those parameters influence each other and the overall quality of the manufactured parts. For example a down shift in material viscosity can be countered with a lower melt temperature but a too low melt temperature can rise problems with surface quality, weld line quality or warpage. So, for every adjustable parameter there is a certain value range in which it can be adjusted without harming another key parameter. A set of those defined parameters with their value ranges in which they can be changed to produce a good part is called a process window.
It is easy to understand that a large process window is desired to be able to counter a wide variety of process changes.

2.4. Weld Lines and Weld Line Characteristics

During the filling stage of the IM process molten material is injected into the cavity in a fountain like pattern (see Chapter 2.5.2). However when the melt front hits an obstacle like a core or a section with a low wall thickness the melt stream is divided into two separate flows (Figure 5). Other possible reasons for two or more melt flows are multiple gating or co-injection [3,10,35,38,40,46,64]. At some point those two flows have to merge again like after the core or when the cavity is filling, pressure rises and therefore areas with lower wall thickness are also filled. The merging happens along a plane over the whole wall thickness in this area. On the molded part surface this merging area can be seen as a line. Those lines are called weld lines or sometimes knit lines.
The main problem with these areas is the inhomogeneity in terms of morphology. This leads to a significant loss of mechanical strength. In unfilled polymers this is mainly caused by the orientation of the molecular chains [29,44], in fiber reinforced polymers the main effect comes from the orientation of the fibers [8].

Weld lines can be divided into two major classes: "hot" and "cold" weld lines. Their classification depends on how they are formed [10,19,34,40,46,55].

The difference between a hot and a cold weld line can be found in the meeting angle of the two involved melt fronts. If two melt fronts meet in an about 0° angle it is called a cold

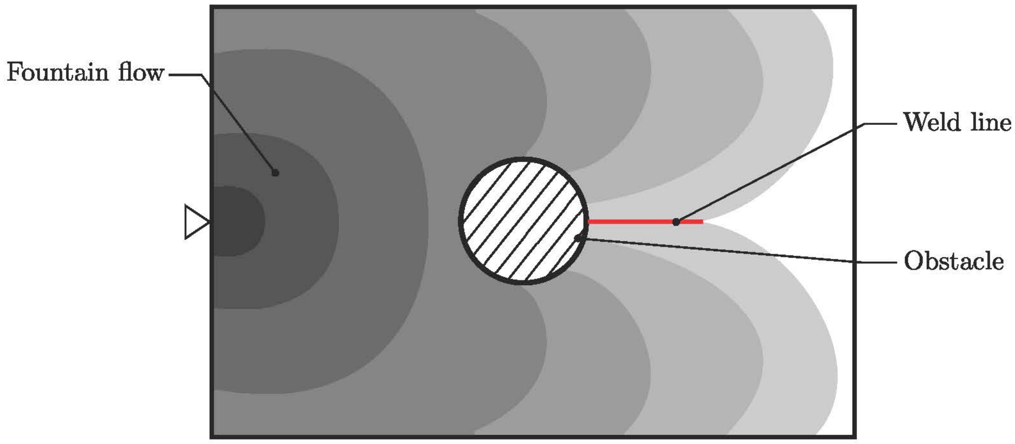


Figure 5: Appearance of a weld line.

weld line. If the angle is more than that it is called a hot weld line. When two melt fronts meet under a 0° angle the flow stops immediately and no interaction can take place (Figure 6, Example a). If the melt fronts meet under a small angle they are "pushed" along the main flow direction as more material is fed into this region. This causes better mixing of the two melt streams and results in a weld line with better mechanical properties than a cold weld line [19, 21, 43, 46, 55]. The transition from cold to hot weld line is not clear cut and can change within one weld line. For example directly behind an obstacle the melt fronts always meet as a cold weld line. Depending on the flow conditions one melt flow can feed more material, then the weld line is dragged towards the side of the smaller melt flow which results in a hot weld line (Figure 6, Example b). Figure 6 shows the dragging of the weld line with a color transition from red (bad- cold weld line) to green (good- hot weld line) the quality transition depending on the meeting angle.

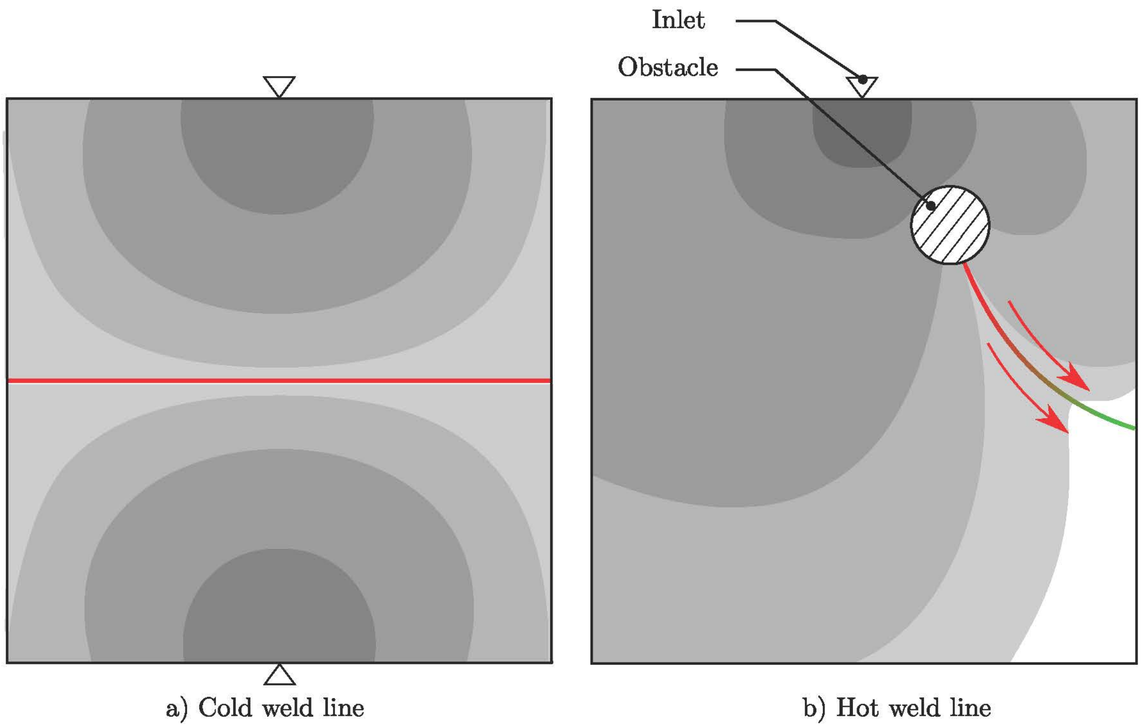


Figure 6: Comparison of the two main types of weld lines (cold in red, hot in green). At b) the hot weld line forms from a cold weld line during filling.

During the formation of a weld line the last volume filled is at the surface of the cavity. Because of the convex melt fronts in this area and the polymer sticking to the cavity a notch is formed and freezes rapidly due to the cold cavity surface. This notch is called a V-notch.
Many studies were made on the formation and the impact of a V-notch [18, 39, 44, 48, 60]. Figure 7 shows the formation of a V-notch as the weld line forms. The reasons for a V-notch to occur is the fountain flow of the plastic melt (for more information about the fountain flow see Chapter 2.5.2) which brings the melt to the V-notch position. When the cavity is almost completely filled the melt surface temperature is significantly lower than when the two melt streams first met. Due to trapped air caused by bad venting or the lack of pressure due to high polymer viscosity caused by low material temperature the mold is not completely filled as it can be seen in Figure 7 and a V-notch is formed. Because of the late meeting of the two melt flows in the surface layers of the two melt streams the inter-diffusion (Chapter 2.5.3) does not have enough time to take place. Therefore the bonding between the melt streams is bad, especially in the surface regions. The bad bonding and the late meeting not only result in bad mechanical properties but also in a visible line around the part's surface at the weld line.

A V-notch can be seen as the scribing of specimen in mechanical testing. Especially in bending failure tests the notch leads to a stress concentration at the bottom of the marking and to a defined place of failure [41, 54].
The influence of the depth of the V-notch on the weld line strength of unreinforced polystyrene (PS) was investigated by Tomari and Harada [59]. To improve the V-notch problem literature generally suggests a lowering of viscosity by increasing temperatures and raising the holding pressure [59, 60].

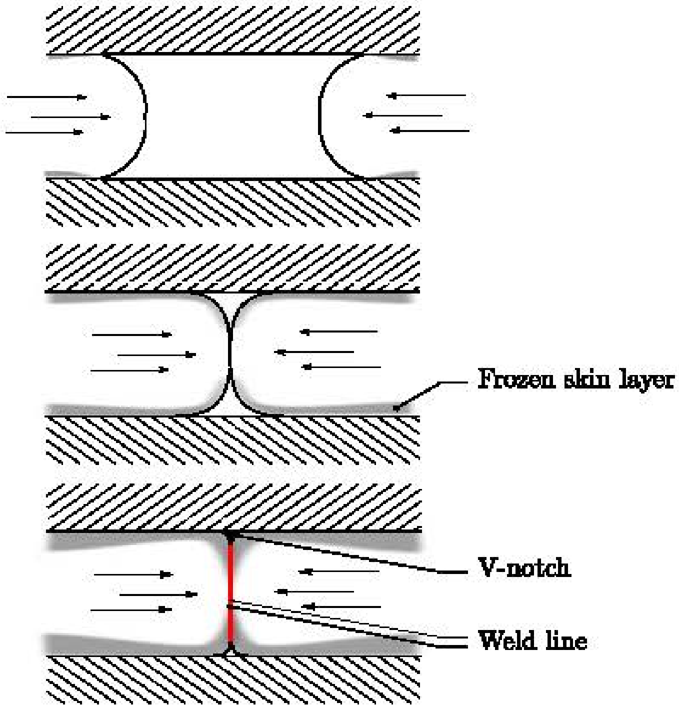


Figure 7: The forming of a V-notch at a weld line. Based on [26]

Hagerman investigated the influence of the V-notch on different types of acrylonitrile-butadiene-styrene (ABS). He showed the influence by carefully polishing the V-notch out of cold weld lines. The polished specimens showed a consistent yield stress of about 85 % of that of a non-weld sample, whereas the unpolished samples showed a wide scatter in yield stress and elongation at break. Hagerman [27] and Malguarnera [40] point out that to achieve a proper weld line quality, venting of the weld line area is an important factor.

2.5. Morphology of Weld Lines

First the morphological background of semi-crystalline thermoplastic materials will be discussed followed by a description of how their properties develop.

2.5.1. Crystallization of Semi-Crystalline Thermoplastics

There are two basic types of thermoplastic polymers, namely amorphous and semi-crystalline. The reason for their difference can be found in their morphology when solid. In general, plastics consist of polymer chains. In fluid state those chains are randomly distributed and are not in a constant relation to each other. In amorphous polymers, if the glass transition temperature T_g is reached during cooling, the polymer solidifies. Amorphous thermoplasts solidify in a random disorder. Semi-crystalline thermoplasts on the other hand show a different behavior during cooling. Semi-crystalline polymers show a second characteristic temperature, the melting temperature T_m. When cooled to T_m the polymer chains arrange themselves lamellar to ordered crystalline regions. This arranging process needs unspecified starting particles, so called nuclei. These can be different polymer molecules, fillers or contaminations like dust. [15, 47]

Although up to 80 % [13] crystalline areas can form in the matrix, the polymer will never fully crystallize. The isolated crystalline areas are connected via inter-crystalline molecules so called tie molecules. Ordered structures need less space, therefore semi-crystalline thermoplasts generally show a higher degree of shrinkage. A higher degree of crystallinity leads to higher density, tensile strength, Young's modulus, hardness, abrasion resistance, solvent resistance and because of higher density, a higher thermal conductivity. On the opposite mechanical damping, impact strength, strain at failure, volume, compressibility, thermal expansion, resistance to stress cracking, swelling, permeation of gases and vapors and transparency decrease with a higher degree of crystallinity. [15]

2.5.2. Molecular Orientation

As mentioned in Chapter 2.5.1 thermoplastic melts are built from randomly distributed entangled polymer chains. During the injection process this bulk of chains is forced through small nozzles and gates under high pressure and has to be distributed into the cavity - a flow direction with a velocity profile is created. Melt shearing caused by different velocities of the imaginary layers is introduced to the melt. Because of the shearing the polymer chains align themselves with a preferred orientation in direction of the main flow direction [5]. The higher the shear rates are the more this effect will occur. Most of the time the melt sticks to the relatively cold mold surface. It cools down and solidifies rapidly in these surface areas. This leads to a freezing of these molecular chain's orientations [20]. Theoretically, if the melt would not be cooled down, after a while molecular resetting forces would cause a restoration of the old random orientation of the polymer chains (Figure 8). This effect is called entropic elasticity [2,17,22,58]. Different frozen-in polymer chain orientation leads to different material behavior both in and perpendicular to the main flow direction. This causes internal stresses and can result in differences in the shrinkage behavior of the material.

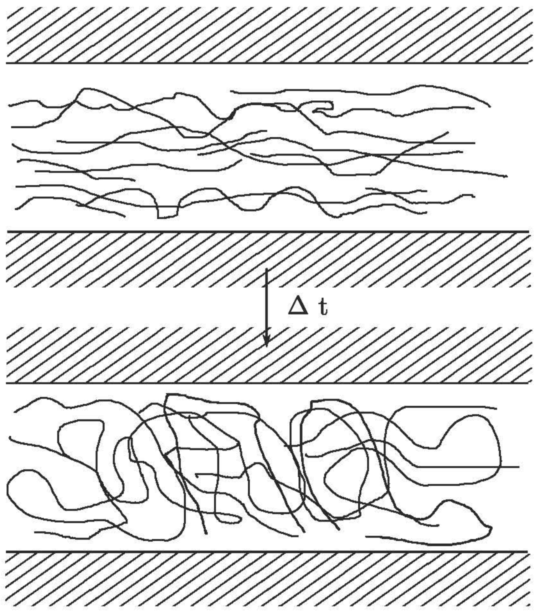


Figure 8: Basic change in morphology due to entropy-elasticity. Based on [14]

Compared to metals, thermoplastic materials generally are bad thermal conductors [12]. The hot, unsolidified core regions are insulated by the frozen outer polymer layers of the sprue or cavity. A bell-shaped velocity profile is created with the highest velocities and the smallest shear rates directly in the center of the melt gate area. Due to this melt velocity profile most of the material is fed from the middle areas. This leads to a so called fountain-flow pattern (Figure 9) [51,56,57].

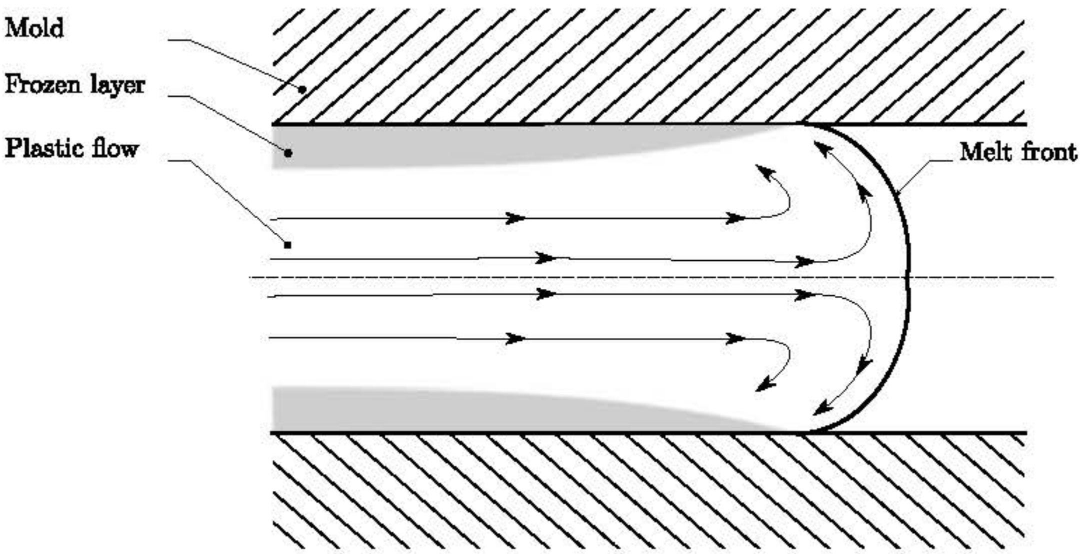


Figure 9: Schematic of the fountain flow inside a flow channel. Based on [26]

When filling a disk-shaped geometry in addition to the described fountain-flow another flow occurs. Given the idea of a disk that is filled from the center, the fed material, as it fills the cavity from the center, has to cover a constantly bigger circumference. To achieve that, the melt flow and especially the melt face has to be constantly expanded perpendicular to the main radial flow direction. During filling, initially the center polymer at the melt front is oriented in the tangential direction but then forced onto the cavity wall, the orientation shifts back to a radial orientation due to the fountain flow. The following material, however, stays in between the surface layers and keeps its tangential orientation. This leads to a three layer structure. The surface layers are oriented in the radial main flow direction, the center layer is oriented perpendicular to it. The thickness of those layers is mainly influenced by the melt temperature and the mold temperature [36].

2.5.3. Molecular Diffusion or Interdiffusion

Interdiffusion is the linking process between two former completely separated melt bodies. If the melt bodies are above the glass transition temperature (T_g) the molecular chains have enough mobility to migrate from one melt surface into the other and entangle themselves with the other melt body to form a strong and uniform bond. This process needs time and runs faster the higher the melt temperature is. However, in the injection molding process there is almost never enough time for a fully developed diffusion between two melt bodies which results in lower bond strength and a mechanical weak spot at the weld line. Figure 10 shows the diffusion and entanglement process schematically. [18,31,44]

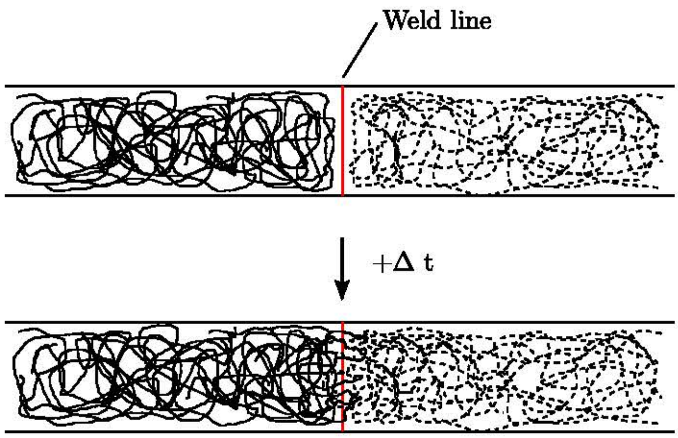


Figure 10: Principle of Interdiffusion. [31]

2.5.4. Fiber Orientation

Like molecules, fillers in plastics are affected by the melt flow direction and align themselves to it but in contrast to molecules, fillers do not show relaxation meaning their orientation is not affected by time or temperature [42].

Fillers such as calcium carbonate, glass spheres or carbon fibers have different geometries. Where calcium carbonate or glass spheres generally show a similar length to width ratio, fibers have a very high ratio. This ratio is called aspect ratio. The higher the aspect ratio is the more anisotropic the filler behaves concerning solid material properties and also processing properties. Spherical fillers are not much affected by flow patterns. High aspect ratios of fillers on the other hand lead to high anisotropic part properties and have significant impact on the weld line properties [53].

Modern thermoplastics are often filled or reinforced with either passive or active fillers. A passive filler like calcium carbonate is mainly used for replacing polymer to make it cheaper without significantly changing the polymer's integrity or properties. Active fillers like fibers, anti-oxidants, fire-retardants influence the properties of the polymer. For better mechanical properties glass fibers or carbon fibers are added to the polymer matrix. They increase the strength and modulus of the thermoplastic matrix. When matrix and fiber are properly linked the fiber takes the load that is applied to the molded part from the relatively weak matrix which results in a much better mechanical performance [47]. However, this reinforcing effect mostly applies for the axial direction of the fiber. Perpendicular to the main fiber axis, the effect is significantly smaller to non-existent. This means fiber-reinforced (FR) polymers show anisotropic material behavior. [12,20,32]

During the injection molding process the fibers flow in the polymer matrix and are also oriented in flow direction. However, they do not succumb the effect of entropic elasticity (Chapter 2.5.2) and stay oriented in the main flow direction. This means process variables like melt temperature at the weld line or process parameters like mold temperature do affect the morphology of the matrix at the weld line but do not help with rearranging the fibers.

2.6. Improving Weld Line Strength

Literature suggests two different concepts for improving weld line strength: either the use of special process and mold techniques or optimizing the standard injection molding process. Concerning this thesis a special technique was already in use and therefore not an option. For this reason this section will focus on the process optimization for short fiber reinforced thermoplastics. For more information about special process and mold techniques see [1,4,6,7,24,25,28,37,38,50,61,62,63,64] which are summarized in [31].

To be able to compare the quality of a weld line with the surrounding flawless material the so called weld line factor (WLF) [8,9,18,43,44,55] is used. The WLF is a simple ratio between the measured e.g. tensile strength of a specimen with and without a weld line. This means the factor can range from 0 to 1. Values close to zero represent very bad weld line properties whereas values close to 1 indicate that the weld line quality for the measured weld line property is very close to flawless material.

2.6.1. Optimization of Process Parameters

Improving weld line strength by using a design of experiment (DoE) to vary several process parameters is a common way to meet that issue. However, literature suggests that there is no general best process setup. For every material/process composition there seems to be a different optimum [40]. Despite this, the results of some selected papers are summed up subsequently.
Selden [55] did extensive research on the behavior of weld lines in filled and unfilled polymer materials. The investigated materials were: 35 wt% glass fiber (GF) reinforced poly-amide (PA), 40 wt% GF reinforced poly-phenylene-sulfide (PPS), poly-propylene (PP) with talcum, unreinforced poly-phenylene-ether (PPE) and unreinforced acrylonitrile-butadiene-styrene (ABS). Research was done on both cold and hot weld lines where hot weld lines generally showed a better performance. As in this thesis only the cold weld lines are of interest, the following paragraph only sums up the cold weld line aspect of Selden's research.

Generally, the WLFs of reinforced polymers are, with values of 0.3 to 0.7, significantly lower than those of unreinforced materials which show WLFs of around 0.9. The investigated IM parameters were: injection rate, holding pressure, melt temperature and mold temperature.

Summing up the results, the investigated parameters did not vary the WLFs in a larger scale. A slight improvement of the weld line strength was achieved with high holding pressure, high melt temperature and low mold temperature. There was no general advice for the injection rate as it highly depends on the polymer. For the reinforced PA a high injection rate decreased the WLF by almost 6 % while increasing the holding pressure increased the WLF by 4 %.

In a study by Cloud et al. [8] on the weld line integrity of PA66, PP, poly-carbonate (PC), poly-sulfone (PSU), styrene-acrylonitrile resin (SAN) and PPS unfilled and fiber reinforced, it was found that the proper venting of the weld line area is crucial for good results. Therefore a mold with a venting system was used. The unfilled samples generally showed high WLFs (PA66 unfilled 0.97). Increasing the fiber content of the polymer from 10 wt% to 40 wt% dropped the WLF (of the tensile strength) from 0.93 to 0.53. Using carbon fibers instead of glass fibers additionally decreased the WLF further down 0.47. Generally, the used PA66 and PC, both with 30 wt% fiber content did not show a sensitive behavior when changing the investigated parameters. Only high holding time seemed to have a significant impact on weld line strength.

To conclude the presented papers unreinforced polymers show about 10 % less strength in weld line areas than in non-disrupted areas. The WLF can be improved by high melt and mold temperature. The loss in weld line strength in reinforced materials is significantly higher, usually up to around 50 %. The injection rate, holding pressure, melt temperature and mold temperature are IM process parameters, which seem to affect the weld line strength the most. In some cases the WLF of unreinforced thermoplastics could be improved to almost bulk material, reinforced materials generally do not show a high sensitivity to the change of process parameters. The gain in weld line strength through optimization lies within a few percent. The weld line strength tends to be improved due to higher melt temperatures and holding pressures. The effect of mold temperature and injection rate seems to be either positive or negative, depending on the material.

2.6.2. Movable Mold Insert System (MMIS)

Prior to the development of this thesis Janko [31] and Kaufmann [33] did extensive research on weld line improvement using a completely new method. Janko developed a passive movable obstacle which is placed directly in the weld line formation area. The weld line improving consists of two factors:

- *Extending weld line length*: Despite the fact that a long weld line makes a part weaker it is important to know the place and geometry of the weld line. As it can be seen in Figure 11 the sealing element consists of concentric rings. Due to a central gate the weld lines will form in these rings over the whole cross section of one ring. The position of the weld lines were determined by IM simulation. The big markings show the main cold weld lines in the element whereas the small ones mark minor weld lines that never showed any problems during all tests because they are hot weld lines. All those weld lines can not be avoided. To still improve the weld line strength the meeting surface of the meeting melt flows should be big in order to offer a big surface for entanglement. It can be seen that only one ring does not show a major weld line. For this thesis only rings with major weld lines are of interest. Therefore only the rings with such major weld lines are numbered beginning at the outermost one with 1 to 8 for the innermost ring.
- *Reorganizing fiber orientation*: As Janko describes "The emerging fiber orientation in a standard weld line area is very disadvantageous to withstand bending loads, so the idea of reorganization of the fibers in this region is obvious. This could be done by adding a pressure difference, which forces a flow through the weld line after formation, used in push-pull and multi-cavity concepts, or by active interference at the time of weld line formation." [31]

Based on these facts Janko developed a new system to force the two meeting melt streams to interact and therefore create a better entanglement of the matrix caused by a better distribution and orientation of the fibers. Figure 12 shows the principle of the developed movable mold insert system (MMIS).
Due to the inclined faces of the obstacle both melt flows are forced to form a large melt flow surface. When the cavity is filled the two melt streams are forced into the small gap between the MMIS and the mold. The MMIS obstacle is pushed out of the cavity by the injection pressure. Because of this pushing-out action small vortices and disruptions are

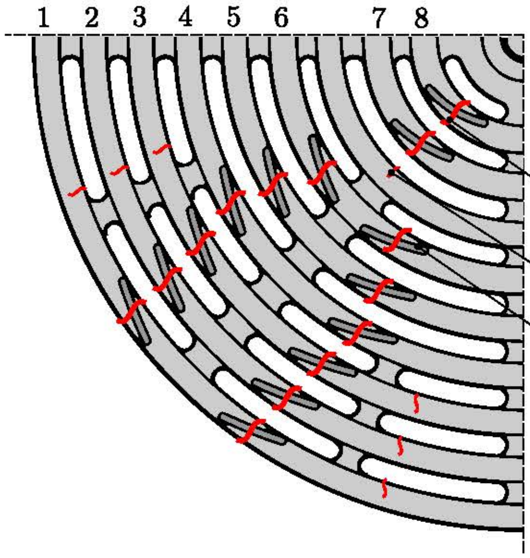


Figure 11: The locations of the weld lines at a 261XP specimen and the correlating positions of the MMISs.

introduced to the melt flow surfaces causing a much bigger weld line surface, a reorganizing of the fibers and significantly better mixing of the two melt flows.
The results of monotone and dynamic flexural tests with a poly-ether-ether-ketone (PEEK) material showed up to about 80 % strength and strain improvement. It was found that the testing direction is a major factor for the improving character of this system as the weld line is asymmetric.

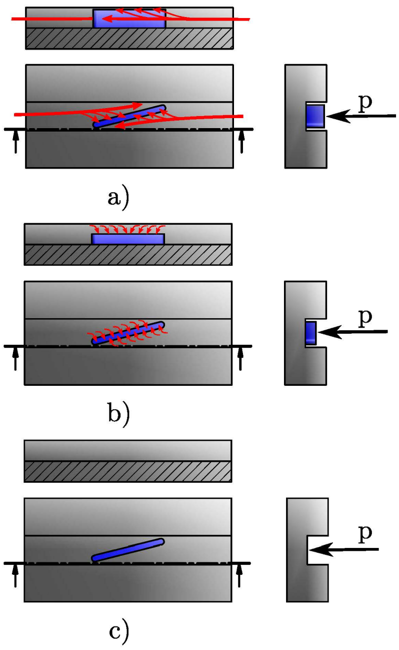


Figure 12: Movement of the blue obstacle due to the rising pressure in the gap between obstacle and upper mold surface from front end position (a) over middle position (b) to rear end position (c), when the obstacle is completely pushed out of the cavity [31].

2.7. Testing Weld Line Strength

With the method described in Chapter 2.6.2 the weld line strength for bending was significantly improved. Kaufmann [33] used a standard tensile stress testing specimen for testing weld line tensile strength and three point flexural strength. He found the weld line strength was not influenced significantly once the MMIS worked in a proper way. Those results were later used by Janko [31]. He used the MMIS in a much more complex geometry and multiple systems per cavity.

2.7.1. Three and Four Point Bend Testing

This section briefly shows the explains the calculation of flexural tension, the setup of a bend test and the difference between three and four point bend testing.

The load curves displayed in Figure 13 and Figure 14 are determined according to the Euler-Bernoulli beam theory with equation (1) [23] (M_b...flexural moment, F...applied force, r...distance from bearing to the point of load):

$$M_b = F \cdot r \tag{1}$$

The section modulus for the given ring geometry shall be constant.
For a constant beam geometry the flexural stress can be calculated by (σ...flexural tension, E_s...section modulus) [23]:

$$\sigma = \frac{M_b}{E_s} \tag{2}$$

Three Point Bend Testing
Figure 13 shows a classic three point bend setup with the correlating flexural moment. Because of the unchanging geometry of the beam the course of the flexural tension is the same (see Equation 2 in Chapter 2.7.1) [22, 23].
The tension maximum is a peak at the center of the beam at the point of force induction.

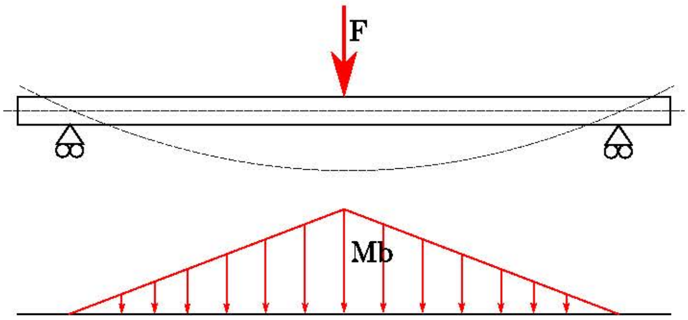


Figure 13: Force and flexural moment distribution in a classic three-point bending test.

Four point bend testing

Figure 14 shows a classic four point bend setup with the correlating flexural moment. The tension maximum extends between the two points of force induction [22, 23].

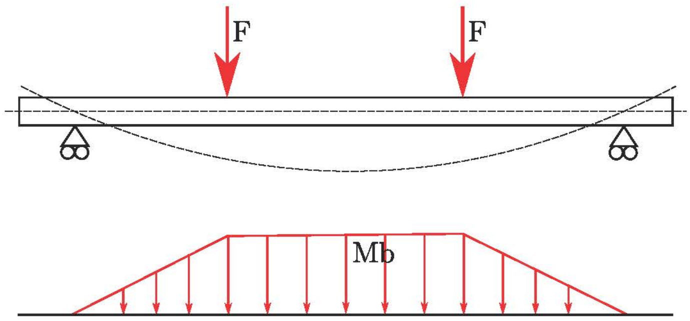


Figure 14: Force and flexural moment distribution in a classic four-point bending test.

To be able to test beams according to this theory the beam needs to be mounted onto a holding fixture. For that purpose either fixed or loose bearings can be used. The classic bend test uses two loose bearings in order to eliminate induced tensile and compression stresses in the outer layers of the beam and to allow the beam to bend in a simple curve deflecting from $r > 0$. For some applications, however, fixed bearings are more accurate in terms of reflecting the use case of the tested part. Fixed bearings prevent the elongation/shortening of the beam and therefore cause additional stresses in the beam. Also the beam cannot evade tensions by already deviating at the bearings but has a defined bend line gradient of zero as a starting condition. So it actually performs a double S-bend (Figure 15).

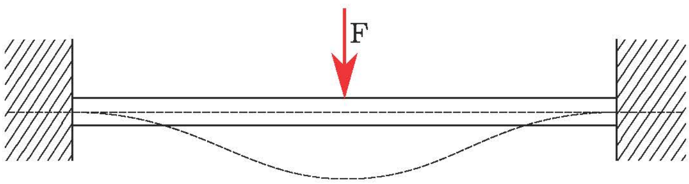


Figure 15: Bending of a beam using a fixed bearing at both ends. Based on [22, 23]

The whole setup should be symmetric. The point of force induction should be in the center of the beam (Figure 16 a). Also the point of force induction should be symmetrical between the two bearings (Figure 16 b).

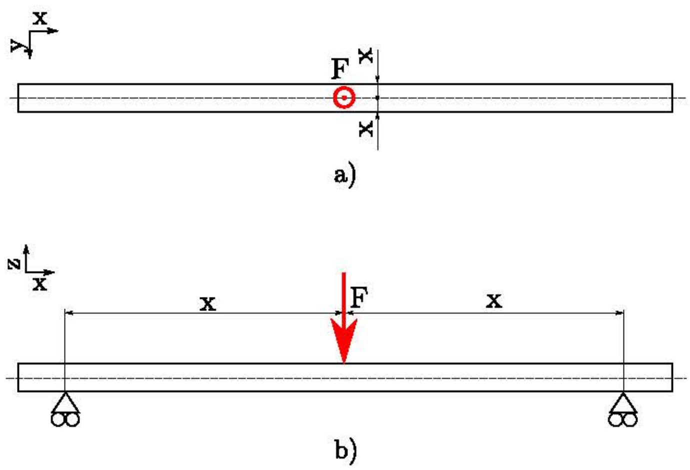


Figure 16: Proper point of force induction for a bend test. Based on [22, 23]

Used bend test setup

To be able to perform a classic comparable three or four point bend test a standardized test specimen such as DIN EN ISO 3167, type A or similar is needed. In the given case of the ring shaped valve plates the major problem is the curvature of the specimen. The result is an asymmetric point of force induction and therefore a very complicated load distribution in the test specimen. Additionally, all rings with their different diameters provide different usable beam lengths. Also the secondary webs interfere with a single beam concept and distribute the applied load partly to other rings. This makes all tests not comparable to each other in terms of comparing weld line strength between rings or different types of valve plates but only between weld lines on the same ring throughout one type of valve plate.

A more detailed explanation of the clamping and force induction can be found in Chapter 3.4.

2.7.2. Prior Test Benches

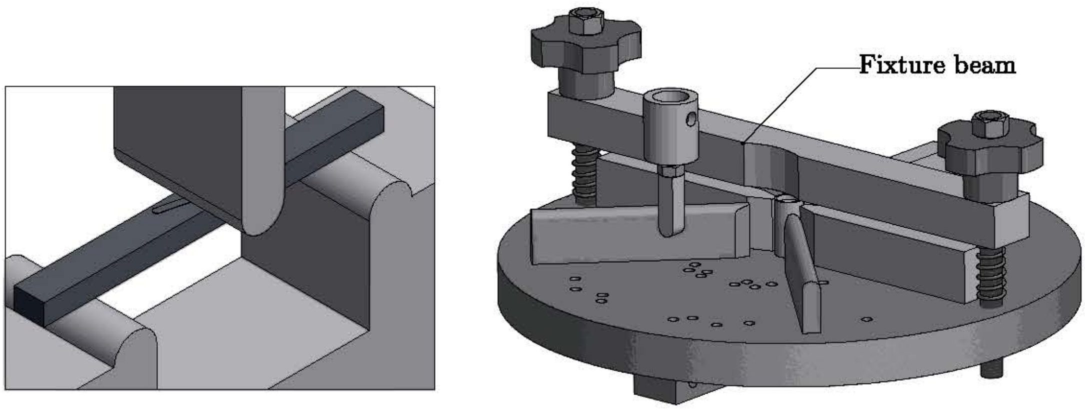
During the development of the MMIS two other test benches have been developed and used to quantify the improvement of weld line strength. Both versions used a Zwick Roell Z010 tensile test machine as main unit and consisted mainly of two bearings and a fixture for the specimen only. The following paragraphs show these two test benches, the problems that occurred and how those problems influenced design decisions for the new test bench.

Version 1: A simple fixture

The first version was used for testing a standard ISO test specimen. It only consisted of two bearings and a simple fixture to keep the specimen in place. The sample preparation was a main issue with this setup. It was very time consuming to cut the center section out of the specimen. Also using the expensive tensile test machine was not very efficient and slow (Figure 17 a).

For the new test bench a quicker test run without cutting out special areas of a specimen was considered as very favorable.

Version 2: A fixture for full sealing elements
Version 2 was designed to accommodate a complete sealing element independent of its diameter. The testing was similar to a three-point bend test with two bearings which could be adjusted to certain angles for perpendicular axes of the bearing and the sealing ring at the point of support. The fixture was achieved with a simple beam mounted on top held by two screws. Advantages of this system compared to the first version were the ability to test unprepared, curved specimens and independence from specimen diameter. Furthermore, it was able to measure more than one ring without unclamping the specimen. Disadvantages were the problem of locating the proper test location. As multiple rings could be measured the test tip of the test machine had to be adjusted each time in terms of x- and y-axis to measure exactly in the middle of the MMIS. The fixture faced a problem of evasion during testing. As the fixture beam was relatively small compared to the size of the specimen it did not stop the specimen from counter bending throughout the whole specimen. This could lead to distorted measurement results. The mounting and un-mounting of the beam took relatively long (Figure 17 b).
The knowledge about behavior and problems with the mentioned test stations influenced the design of the new test station (Chapter 3.4) significantly.



a) b)

Figure 17: a) Version 1: a simple fixture; b) Version 2: a fixture for full sealing elements [31].

2.8. Investigated Material

For all tests a poly-ether-ether-ketone (PEEK) was used. As a member of the poly-aryl-ether-ketone (PAEK) thermoplastics it is characterized by phenylene rings linked with oxygen bridges, either ether or carbonyl groups (ketones) [52]. The basic molecular structure of PEEK is shown in Figure 18.

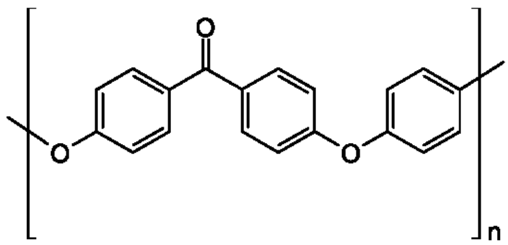


Figure 18: Basic chemical structure of poly-ether-ether-ketone.

The structure of the polymer provides excellent mechanical and thermal properties. The material with a glass transtition temperature (T_g) of about 145 °C and a long term operation temperature of approximately 250 °C [12,13] is suitable for high performance and high temperature applications. The crystallinity ranges up to 48 % [13] which depends on processing and heat treatment. PEEK resists a wide range of chemicals. Only nitric acids and some halogenated hydrocarbons affect the material. Sulfuric acid at higher concentrations dissolve the polymer [13]. PEEK can be characterized by the following attributes:

- High tensile and flexural strength
- High impact resistance
- Good long-term mechanical properties and dimensional stability
- High fatigue strength
- Excellent hydrolysis resistance (up to 280 °C at 18 bar)
- Excellent wear and abrasion resistance

3. Experimental

The experimental section deals with the used equipment, materials, procedures and the design of the experiments.

3.1. Used Polymer

For all experiments a PEEK with 30 wt% carbon fiber was used. The polymer was compounded by Solvay.

3.2. Test Specimen

For this thesis a valve plate (Figure 3) with a diameter of 261 mm, nine concentric rings and 56 MMISs was used. On every ring with MMISs, four of four weld lines at the two inner rings and four out of eight weld lines at the six outer rings were tested. These specimens are referred to simply as 261XP from now on.

3.3. Machine

All specimens were produced on a fully electric Engel e-Motion 940/280T injection molding machine using a Wittmann Battenfeld Silmax E50/Drymax dryer and a Wittman Battenfeld Tempro plusC 180 heating unit. The main features of the injection molding machine (Table 1), dryer (Table 2) and the temperature control unit (Table 3) are listed below.

Table 1: Basic data of the injection molding machine.

Name		Engel e-Motion 940/280T
Manufacturer		ENGEL Austria GmbH
Clamping Unit		
Clamping force	kN	2800
Tie-bar clearance	mm	940
Opening stroke	mm	600
Injection Unit		
Screw diameter	mm	55
Stroke volume	cm^3	350
Injection rate	cm^3/s	235
Spec. injection pressure	bar	2200
Contact force	kN	50

Table 2: Basic data of the dryer.

Name		Silmax E50/Drymax
Manufacturer		Wittman Kunststoffgeräte GmbH
Volume	l	50
Max. temperature	°C	160

Table 3: Basic data of the temperature control unit.

Name		Tempro plusC 180
Manufacturer		Wittman Kunststoffgeräte GmbH
Number of circuits		2
Flow rate	l/min	12 - 30
Max. temperature	°C	180
Operating pressure	bar	3,5 - 5

3.4. Test Station

Based on earlier test station designs by Janko [31] a new test bench was designed. The design requirements and the final test station design are stated subsequently.

3.4.1. Design Requirements

- *Stand-alone test station*: The test station must be able to operate on its own without any further machines or equipment (unlike Jankos [31] approach who used a Zwick Roell Z010 tensile test machine).
- *Specimen independent*: The test station must be able to test a variety of different sealing elements which differ in diameter, thickness, number of weld lines, position of weld lines etc. There are also sealing elements which are of the same type but differ in diameter.
- *Quick and easy testing*: An average machine operator on the shop floor must be able to use the test station during one molding cycle with a minimum amount of training and still be able to perform reliable measurements.
- *Rugged design*: The test station must be sufficiently rugged to be used on the shop floor in contrast to a laboratory. Therefore it has to withstand rough handling, dust, dirt etc.
- *Machine capability*: The test station must be able to deliver reproducible values.
- *Independent testing of rings*: As the rings are all connected to each other they influence each other during testing. However, if one is broken it does not take any load any more. To exclude this problem the test station must be able to test rings as independently as possible.
- *Solving known problems*: The test station design must fix or at least mitigate known problems with previous test stations (Chapter 2.7.2).

3.4.2. Test Station Design

Based on these requirements a test station design was developed (Figure 20) using the CAD software PTC Creo 2.0 [49].
The test station consists of four main components:

- *Manual press*: The press is a standard toggle press by Burster GmbH & Co Kg. Because of a too small working space the head of the press had to be adapted. The top clamping screw and the spindle were removed. The two remaining clamping screws still provide enough safety but for further test stations of this size and kind of sensors a toggle press with a bigger working space should be considered.

- *Test station base unit*: This component is mounted on the toggle press. Once adjusted properly it does not need to be changed regardless of what sealing element is tested. The only part that has to be changed for each type of sealing element is the locking rail because of the different distances between the rings and the different amount of MMISs per sealing element. The locking rail works with a lock guard mounted at the base plate.

- *Carrier*: There are multiple carriers for this test station. For every main type of sealing element an individual carrier and lock rail is manufactured. This is necessary because not only the radial distance between two weld lines is different on each sealing element design but also their position and quantity. For every test session the appropriate carrier and lock rail has to be mounted onto the base unit. The carrier itself consists of a base, a pressure plate, two column guidances and two hand operated fasteners. The specimen is inserted between the base and the pressure plate.

  The basic mounting setup in the carrier can be seen in Figure 19. Different to classic bend test setups (compare with Chapter 2.7.1) the clamping is a double sided fixed bearing. This is because of the counter-bending of the specimen during testing meaning the tested ring can deviate much more before breaking. As a manual toggle press is used for inducing the force only a very small proportion of the toggle press's stroke can provide the full force necessary to break the test specimen. Using fixed bearings increases the breaking force of a ring by reducing the level of freedom and introducing more tensile and compressive stresses during bending – the gain of force by reducing the needed stroke of the toggle press is still a key advantage. Also allowing the specimen to counter-bend would mean getting even more influences from other rings into the tested ring as the other webs connect each ring and transmit forces.

  Another problem introduced by the shape of the specimen is the distance between the bearings and the point of force (x) (see Figure 19). This means a form of torsion is added to the load characteristic of the beam.

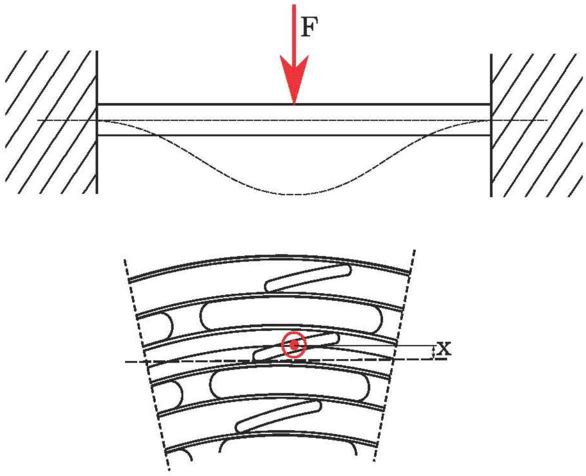


Figure 19: The applied bend setup for the test station. The bearings are positioned at the main and secondary webs if possible. The distance between the bearings is limited on one hand by the symmetric distance between the MMIS and the next web and on the other hand by the fact that the shorter the distance is the higher the needed force for breaking will be.

- *Sensor equipment*: To measure the weld line strength a strain gauge sensor accompanied by a range sensor was chosen. To evaluate the results a Burster Digiforce 9310 evaluation unit accompanied by a selection-switch was used. The data sheets of the sensors can be found in appendix A.

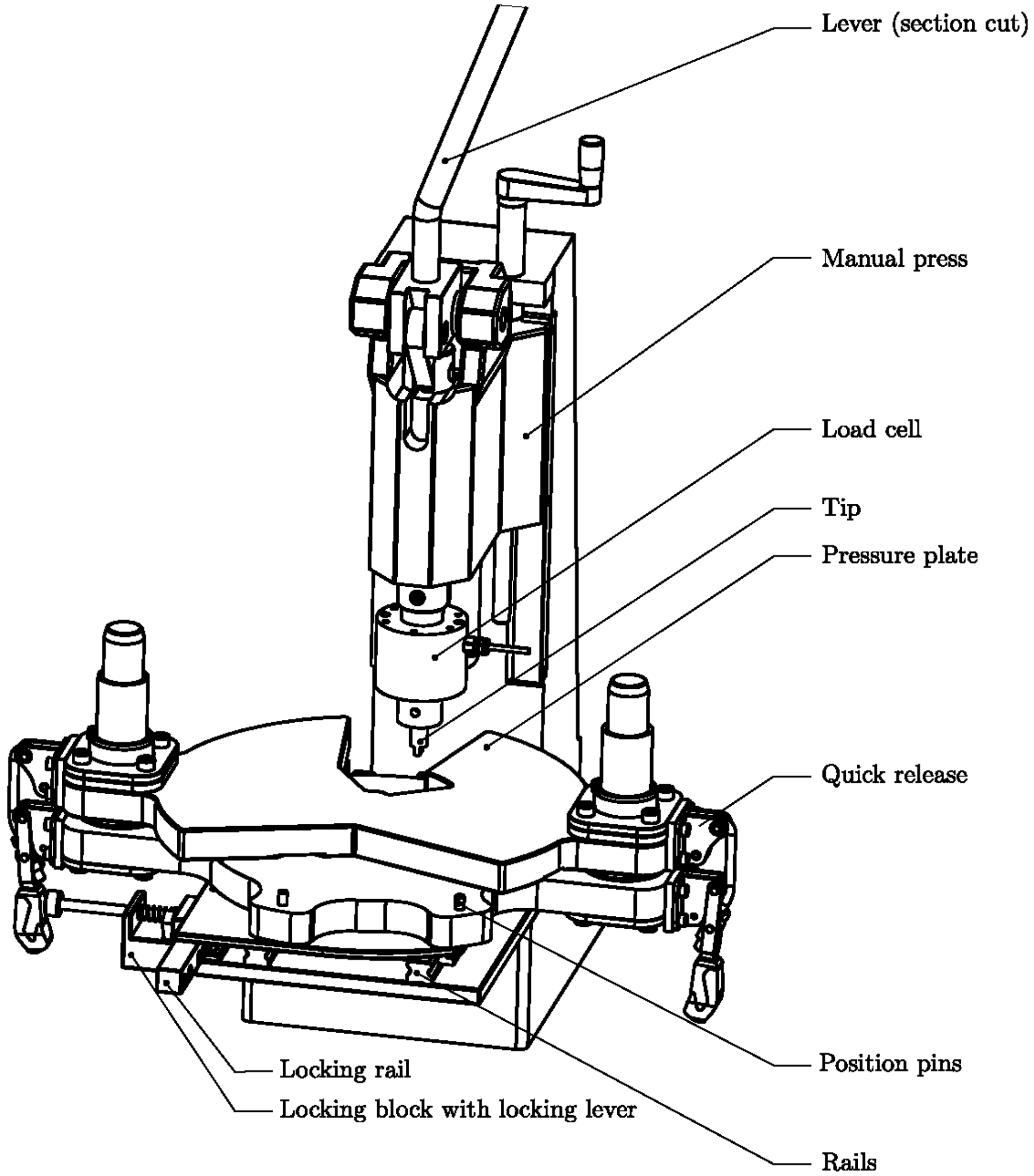


Figure 20: Schematic of the test station.

A complete collection of part designs, assemblies and technical drawings can be found in appendix B and C.

3.4.3. Testing Process

To measure an accurate weld line strength the measurement must be done according to the following procedure:

- *Remove dirt and dust*: Make sure no foreign objects or particles are on the test station or the specimen. Compressed air can be used to remove those objects or particles. Especially the depression in the base of the carrier must be checked for bits and pieces that might have broken off from the last specimen tested.
- *Move carrier to utmost position*: Lock the carrier in the position that is closest to you.
- *Insert sealing element*: Make sure the centering pins are at the correct position for the sealing element type. Position the sealing element using the two pins on the carrier base plate. Make sure the pins are centering the element at the main webs not the secondary webs.
- *Apply pressure*: Lock the valve plate by pushing down the two levers of the quick release fasteners mounted on the side of the test station. Before starting the test, check if both levers need the same amount of force to lock. It is sufficient to simply check if all screw nuts on both levers are in the same position on the fastening hooks. If not, adjust the screw nuts.
- *Test the mounted specimen*: Activate the DigiControl software. Using F3 starts the measurement mode. Use the turn-switch to set program "1". Pull down the lever until the test tip is almost touching the specimen. Slowly proceed, until the DigiControl automatically starts the actual measurement. Apply force until the specimen breaks and/or the lever is fully pulled down to its end position. Release the lever. Unlock the carrier and push it to the next position until it locks automatically. Use both hands to assist the carrier with turning itself into the right angle while moving towards the press. This is important especially for bigger carriers. Use the turn-switch to switch to the next program. Repeat until all weld lines are tested. Move carrier to the utmost position and lock it. Loosen the fasteners, remove the plate and turn it counter-clockwise to the next set of weld lines and insert it again. Fasten the pressure plate again, make sure program "1" is selected and start testing again. Repeat until all sets of weld lines are tested. Hit the "Return" -key on the PC to stop the test run.

  Go to the analysis program, select the measured valve plate type and search the correct path of the generated data. The correct path can be found in the DigiControl settings. Set the desired plate number and the setting. Press "Go". After a while a new entry in the top right list box appears and can be analyzed. Every set of data that is found in the given directory is displayed in this list box and can be analyzed. After all specimens are tested, define a protocol directory and press "End Testing". All datasets in the list box will be saved to this location and an additional full report is created.

3.5. Design of Experiments (DoE)

This section deals with the possible process parameters to compensate the changing process conditions, explains why two specific process parameters were chosen for the experiments and subsequently gives an overview of the selected process parameters used for all tests.

During the development of the MMIS and a working production process the values for process parameters listed in Table 4 have been successfully applied. To meet altering process conditions the following process parameters can be adjusted to maintain a stable production process specifically using the MMIS.

- *Switch-over point:* A later switch-over point can help filling the cavity more quickly using injection pressure instead of hold pressure which is usually lower resulting in a higher melt temperature at the very end of the filling phase. This results in a better trigger behavior of the MMIS as much as a better pressure distribution during the hold phase. However, setting the switch-over too late would not only harm the injection molding machine but also the mold and specifically the MMIS could be severely damaged. A volume sensitive switch-over argument was used for this process (see Chapter 2.2).
- *Feed speed and back pressure:* A higher feed speed together with higher back pressure results in a higher shear rate of the material resulting in a higher energy entry and distribution in the polymer. A problem with high shear rates is the degeneration of the polymer. A significant reduction of the molecular weight takes place. Fibers used as reinforcement in the polymer are sheared, eventually brake and result in a lower average fiber length which lowers the overall mechanical properties of the polymer. In the given case, the feed speed is set almost at the maximum of the machine's capabilities. The remarkably high viscosity of the used polymer needs very high torque at the screw. Lowering this process parameter, although possibly keeping a higher molecular weight, would result in a worse heat and melt distribution which, in this very injection molding process, is known to cause problems with insufficient and unstable injection speed.
- *Injection speed and max. injection pressure:* The injection speed is a very important and versatile process parameter. It influences not only the filling time, viscosity, shearing with filler distribution etc. but also melt temperature. For the MMIS to work it is crucial to maintain a high melt temperature. The higher the injection speed is the more pressure is needed to maintain the mentioned injection rate. As a result, injection speed and maximum injection pressure are linked via the viscosity of the material. During the process development, it was found that a high injection speed is suitable for triggering the MMIS and a satisfying part surface quality. Using a high injection rate of $100\,\mathrm{cm^3/s}$ resulted in reaching the maximum injection pressure of the machine. This means regardless of the goal of $100\,\mathrm{cm^3/s}$ the machine cannot exceed its limit of about 1800 bar injection pressure. If the pressure limit is reached the injection speed will drop below $100\,\mathrm{cm^3/s}$. This is a machine based limitation. Therefore it is suitable to be able to lower the injection speed to stay below the maximum pressure level so the machine can adjust injection pressure to maintain the desired injection rate and not only work on its absolute maximum.

- *Hold pressure and hold time:* Hold pressure and time is mainly used to completely fill the cavity, prevent parts from shrinking and warping. The influence of these process parameters on valve plate geometry and the MMIS was analyzed by Janko [31].
- *Temperatures:* For the MMIS to work the temperature of the melt stream, the melt front and the temperature of the obstacle itself is crucial. During the production process development the melt temperature was raised to 425 °C which is already the absolute maximum the polymer can take before degrading. Lower temperatures showed pressure problems, untriggered MMISs and in some cases very bad weld line quality. To keep the viscosity of the polymer low not only the polymer can be heated but also the mold. The occured problem with a higher mold temperature was sticking [31]. Also the cycle time which is already very high, due to the wall thickness and temperature of the part, is extended.

From the given parameters, the switch-over point and the injection speed seemed to have the highest potential and were chosen for optimization and verification of their influences and possible alterations to define the process window (for a more detailed explanation of the process window see Chapter 2.3). The switch-over point was determined with a fill study. However, it was not optimized. Because of the triggering of some of the inner MMISs the cavity volume changes significantly and the switch-over point can possibly be set later than expected. The given problems with the high injection speed and the maximum possible injection pressure led to the desire of lowering the injection speed without changing the weld line quality. The setup for the production run can be seen in Table 4. Subsequently, the DoE with altering switch-over points and injection speeds can be found in Table 5. The setting used for the production run is called Setting 1. This setting is also used as part of the DoE. The additional settings for the DoE are called Setting 2 to Setting 9.

Table 4: Process Setup of the Production Run: Setting 1

Injection Unit		
Dosing volume	cm^3	380
Switch-over point	cm^3	44
Dosing rate	rpm	120
Back pressure	bar	100
Injection rate	cm^3/s	100 const.
Max. injection pressure	bar	1810
Hold pressure profile	bar-s	820-0//820-25//600-32//100-35
Nozzle contact force	kN	10
Clamping unit		
Clamping force	kN	2500
Cooling time	s	50
Temperatures		
Barrel (nozzle to feed)	°C	425-425-425-420-415-60
Mold A-side (inner-outer)	°C	190-150
Mold B-side (inner-outer)	°C	190-150
Mold base water	°C	90

Table 5: Design of experiment; Setting 1-9 with Setting 1 being the production setting.

Setting	1	2	3	4	5	6	7	8	9
Switch-over point (cm^3)	44	34	54	54	54	34	34	44	44
Injection rate (cm^3/s)	100	100	100	50	70	50	70	70	50

4. Results and Discussion

This section deals with results taken from the evaluation of the DoE (Chapter 3.5). Also a closer look on the process over time is taken as the process stability is a major factor for a high quality production.

4.1. Analysis of Testing Process

According to Chapter 2.7 the test specimen with the clamping should be symmetric at the xz-layer. In this case this is not possible as the beam part of the specimen is curved (Figure 19). This means a torsion moment and asymmetric stresses are introduced to the beam.
Another problem can be observed when looking at the point of force induction. As mentioned in Chapter 3.4.1 the test station must be easy and quick to use. So the station is designed in a way that molded semi-finished valve plates can be tested without further manufacturing except for removing the sprue by simply breaking it off by hand or with a wrench. This means some marking from the MMIS is still on the ring at the desired point of force induction as the obstacle of the MMIS moves further out of the cavity than the ring geometry is machined into the mold (Figure 21). This is because of the mold defects remaining on the surface caused by flow and the moving of the obstacle. To be able to remove them easily the markings stick up a little bit. Because of this elevated area, the line tip of the test tip will be reduced to a point causing a pressure tension peak. Depending on the weld line quality the needed force to actually break the test tip deforms the elevated MMIS mark causing an undefined shift in the force-displacement diagram. This must be considered when the graphs are analyzed.

Figure 21: The markings that occur during testing on the obstacle markings.

In some cases a bad weld line can be instantly determined by looking at the fracture surface. The worst case is pictured in Figure 22 a). In this case the ring broke along the induced weld line geometry which means no interaction had taken place between the two melt streams. These weld lines are typically very weak. Figure 22 b) shows a typical radial fracture surface of good weld lines.

a) b)

Figure 22: a) a typical bad weld line fracture surface. b) a typical good weld line fracture surface.

4.2. Analysis of Startup and Production Run

As usual in injection molding a production run is accompanied by a previous startup phase of the process to eject degenerated material and to heat up the mold. In this case, especially the MMIS had to be heated up in order to work properly.
From experience, it takes about 5 to 10 shots to finally trigger all MMISs. Usually ring 7 and 8, the most inner rings, almost always trigger at the first shot. This is because of the high injection pressure these rings get during filling. Also, the outermost rings, ring 1 and 2, mostly trigger after the first few shots.

The reason for this behavior can be found in the filling and holding phase of the molding process. During filling the pressure at the inner MMISs raises as the melt front proceeds to the outer areas. The further out the MMISs are the lower is the pressure of the melt being directly in contact with them. For the inner MMISs the pressure during filling is already high enough to trigger them. The pressure at every MMIS raises until the cavity is filled up to 99 %. This is the point of switch-over.

The last areas that are filled are the areas of the weld lines of ring 1. As the melt that just hit the obstacle, immediately gets the full hold pressure, the melt stream does not cool down at the obstacle and easily raises it. In the middle areas of ring 3-6 the melt flow hits the obstacles and stops but does not have enough pressure yet to raise the obstacle. It remains at the still cold obstacle, cools down and eventually even begins to stick to the obstacle. As hold pressure is applied to the melt, the pressure level in the whole part rises to almost the same level ([11]). However, because of the cooled down melt at the obstacle there is not enough pressure to force the too cool melt under the obstacle to raise it. This problem can only be met by heating up the obstacles during startup from a cold mold. Once the mold and the obstacles are heated up to a certain level all MMISs seem to work in the same way.

The first shots, the startup phase and the current production run all used Setting 1. From the moment, all MMISs triggered the recorded startup phase began (Usually after about five shots). This was because sometimes parts got stuck on the untriggered MMISs and had to be removed manually which caused delay in the mold cycle and a cool-down of the mold. The startup phase was controlled semi-automatically to ensure no parts remained stuck in the mold. After the startup phase the production run began and was controlled automatically. The set quantity for the startup phase was 10 parts. Then 25 parts where molded in a production run.

Figure 23, 24, 25 and 26 show the full run consisting of 10 shots startup and additional 25 shots production adding up to 35 consecutive shots of Setting 1. The black graph shows the mean force of four weld lines that was necessary to break the weld line. The standard deviation of these four weld lines is displayed in red. If a set of four tested weld lines represented by one black data point shows a standard deviation of more than double the mean standard deviation of all 35 tested specimens it is considered an outlier and marked red.

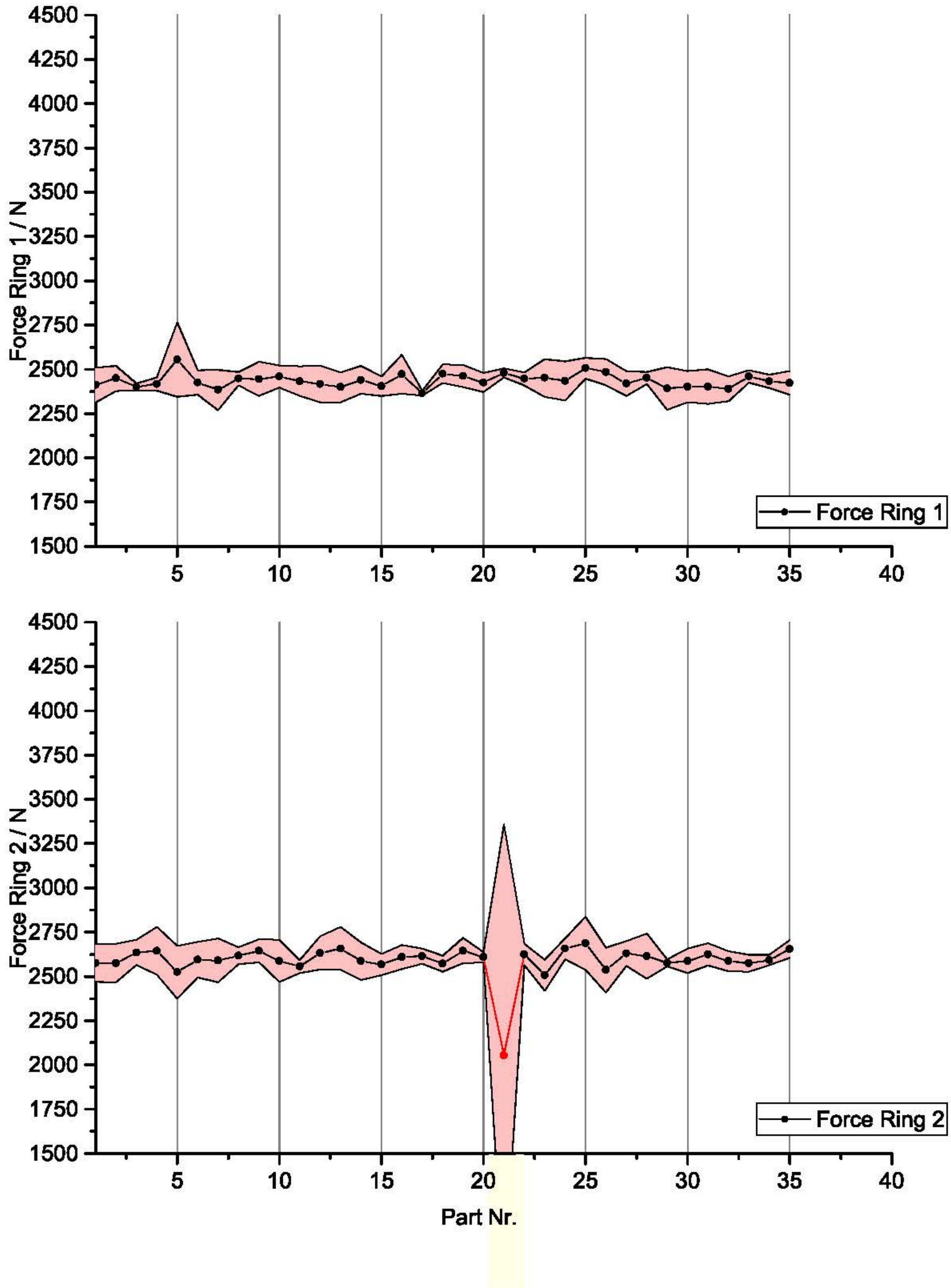


Figure 23: Results for weld line strength, ring 1 to 2 during production run including 10 preceding startup shots.

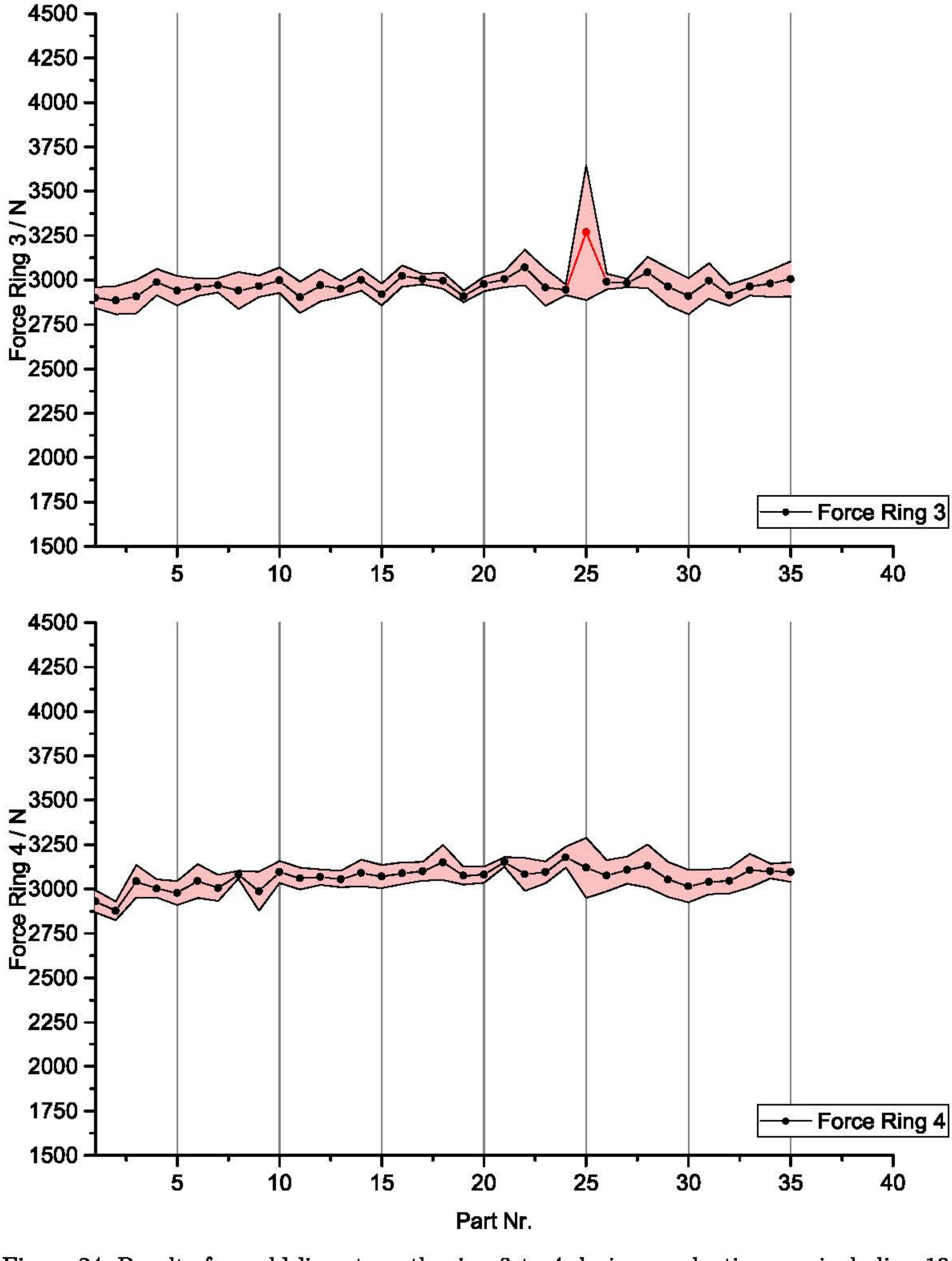


Figure 24: Results for weld line strength, ring 3 to 4 during production run including 10 preceding startup shots.

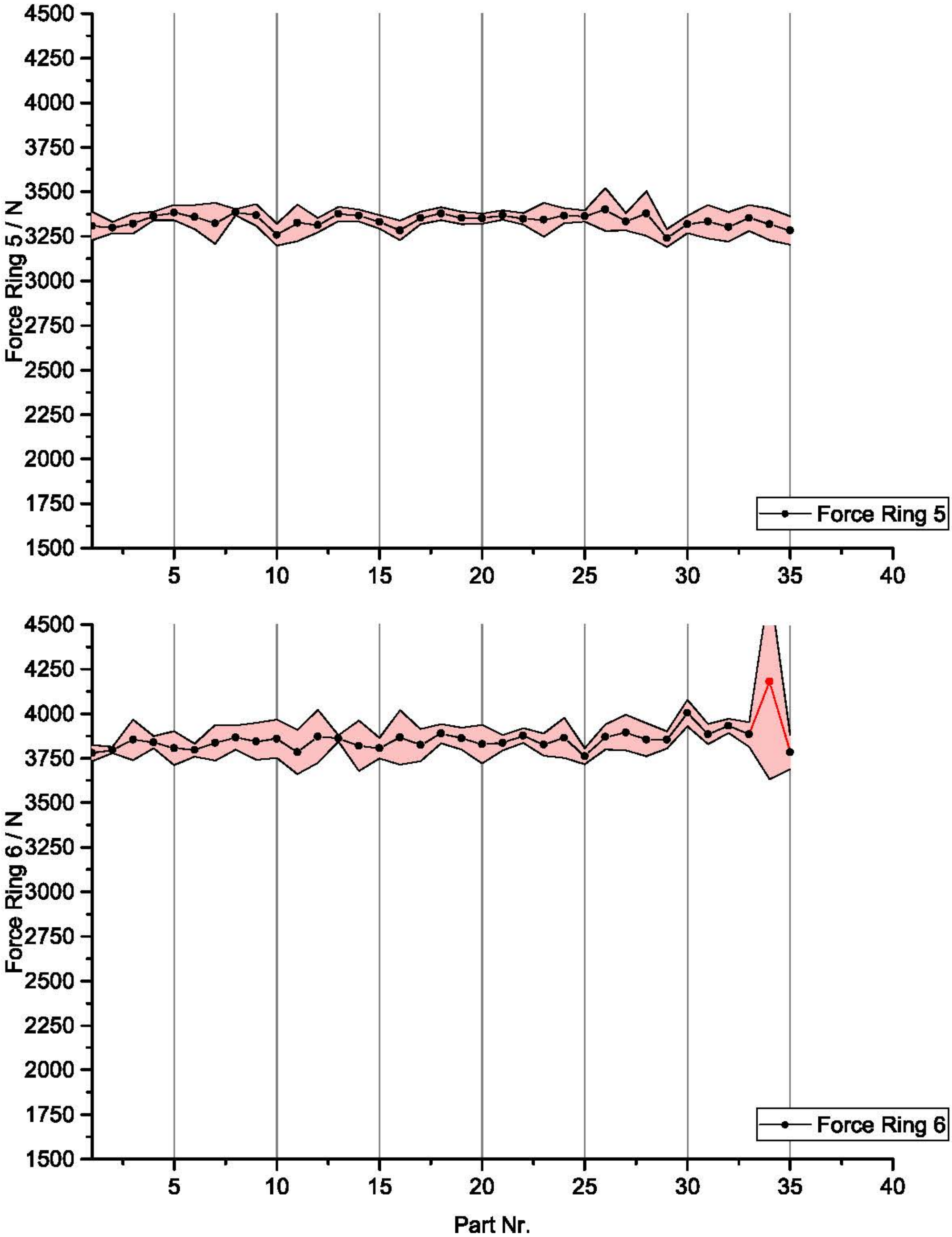


Figure 25: Results for weld line strength, ring 5 to 6 during production run including 10 preceding startup shots.

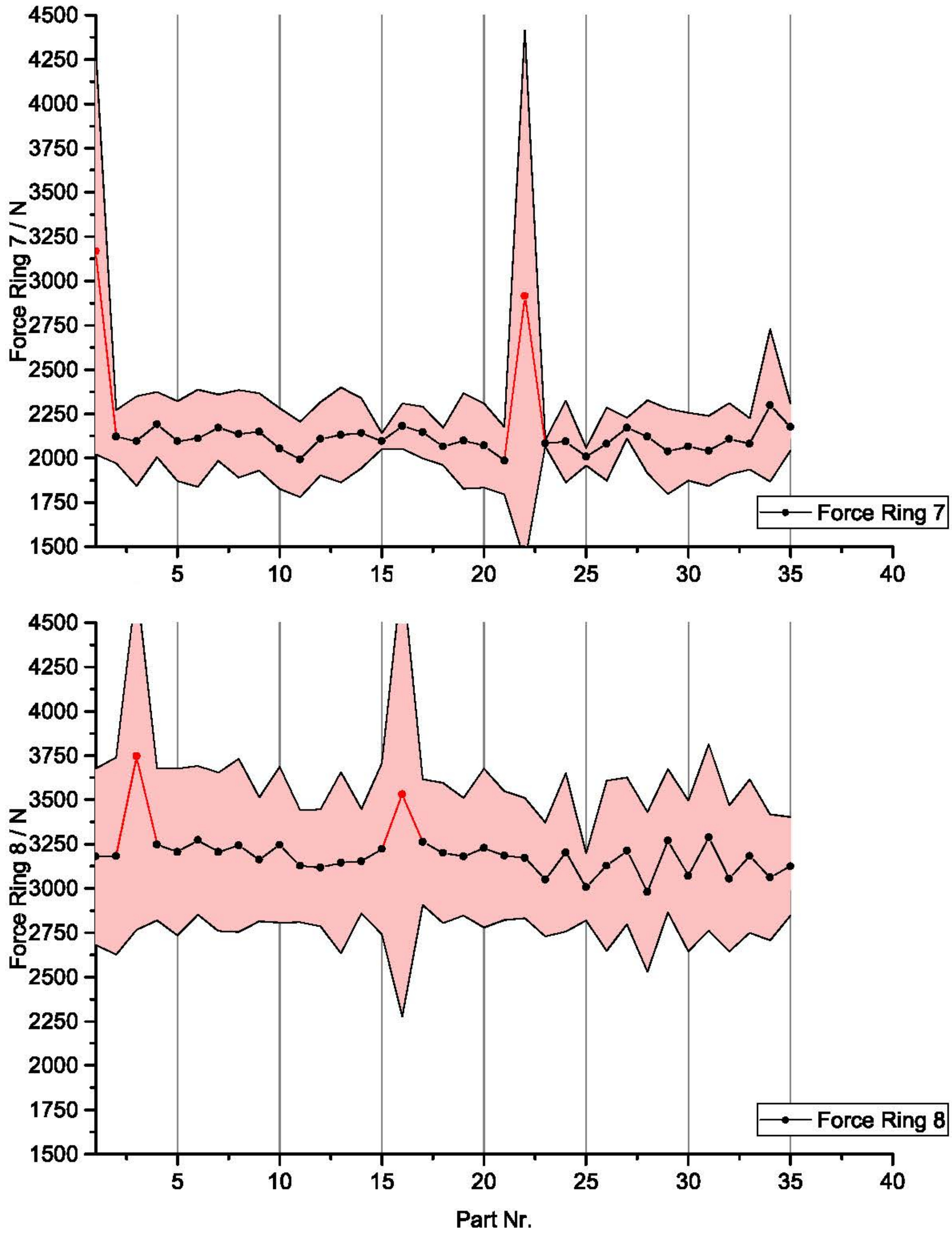


Figure 26: Results for weld line strength, ring 7 to 8 during production run including 10 preceding startup shots.

As the testing conditions for each ring are not comparable to each other also the level of force cannot be compared between the rings. Within one ring, even including the startup phase, there did not seem to be any changes in weld line strength once the MMIS was triggered.
Some parts seemed to show remarkably high weld line strength (eg. Ring 6, Part 34) but also the standard deviation was very high. This leads to the assumption of outliers. One possible explanation for those outliers could be found during testing of ring 7 and 8. The radius of ring 7 and 8 is so small, when the first weld line of those two rings was tested, usually the whole ring shattered because of its stiffness and sometimes parts broke out of the ring remaining inside the carrier. This was observed mainly at ring 7 and 8 but also happened at other rings.
Most of the time the shattering happened when not the actual weld line broke but the ring itself mostly near a main or secondary web. Even if not the weld line broke but the specimen itself, it was still considered an integral failure and counted as weld line strength. In this case the weld line strength can be seen as the same as bulk material strength. As a ring shatters, small pieces can remain in the carrier and work as a support for other rings when lying directly below them, lowering the free beam length for bending and therefore raising the level of force needed to break the beam. The much higher levels of force were detected by the operator of the test station. After checking the carrier, the remaining shattered parts were removed and the other three weld lines were tested normally. This explains why all tested parts with remarkably high force values also show a high standard deviation at these rings.
Another result is the average standard deviation of the rings (Listed in Table 6).

Table 6: Standard deviation per ring.

	Avg. w.l. strength / N	Avg. std. dev. / N	Avg. std. dev. / %
Ring 1	2436	73	3.0
Ring 2	2587	115	4.4
Ring 3	2974	76	2.6
Ring 4	3065	72	2.3
Ring 5	3338	58	1.7
Ring 6	3857	91	2.3
Ring 7	2160	255	11.8
Ring 8	3196	447	14.0

While ring 1 to 6 show an average standard deviation of less than 5 %, ring 7 and 8 have a considerably higher level of over 10 % of their average weld line strength. As mentioned before when testing the first weld line of ring 7 and 8 the rings often shattered, destroying the ring geometry completely. As explained in Chapter 3.4.1 the test station should be able to test each ring and each weld line as independently as possible. However, at these two rings it seemed the structural integrity was destroyed to a point where the pressure plate could not keep up the stiffness of the ring to the needed level of force. It was observed that the main webs connecting the four sections of the inner rings just bent and cracked leading to a much lower force till failure. This behavior, together with the force value of the first weld line with intact ring geometry results in a significantly higher standard deviation of the inner rings.

4.3. Shifts of Weld Line Strength and Standard Deviation

For a stable production it is necessary to make sure no trends or shifts occur as a result of changing conditions e.g. temperature. As it can be seen in Figure 27 there is almost no shift detectable over 35 parts of each ring. The temperature was taken from the movable side's inner temperature sensor which showed the highest changes in temperature during production. From earlier production runs it is known that the temperature stabilizes at about 182 °C.

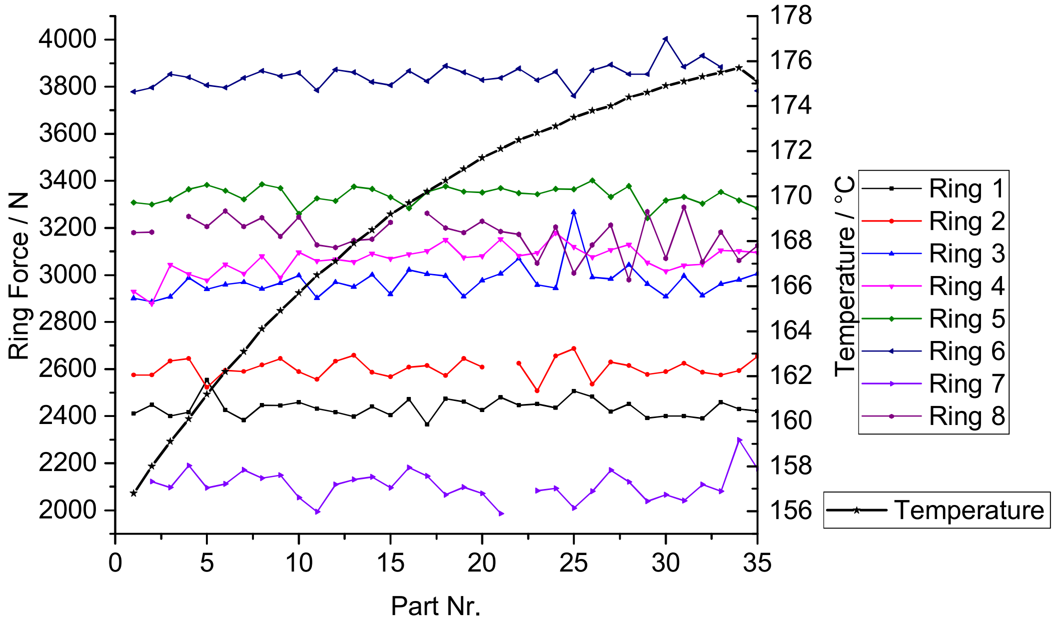


Figure 27: The average weld line strength per ring of all eight rings over the period of 35 shots. The significantly increasing temperature did not seam to influence the weld line quality. For a better overview the outliers have been removed.

Taking the standard deviation (see table 6) into account there is no significant change in weld line strength starting from part number 1 to 35.
Summarizing the temperature influence it can be stated that the weld line strength, once all MMISs trigger, is mold temperature independent. Over the whole logged production cycle the mold temperature was changing from about 430 K (157 °C) to 448 K (175 °C) which means a temperature increase of about 18 K without significantly influencing the weld line strength (Figure 27). This seems to be inconsistent with the statement that the

MMISs are too cold to work during the first injections. Considering the fact that the melt temperature is somewhere close to 673 K (400 °C) and the mold at less than 473 K (200 °C) the assumption can be made that the temperature of the mold is not important but the temperature of the MMISs. The obstacles are very small and have a lot of conjoint surface with the much hotter melt. After a few shots, the energy introduced into the MMISs region by the melt and the obstacles of the MMISs which work like heat conductors could be enough to heat up the obstacles and the area around the MMISs so the obstacle can keep enough heat during its pushed-back state to finally work in the desired way. As this only happens in a small area the heat sensor does not detect those small changes in temperature as the energy input into the mold by the rest of the cooling material has a substantially higher impact.

A high-quality process can be characterized as a process with a small standard deviation. For this reason it is interesting to track the progress of the standard deviation during the production run. Figures 28 and 29 show the standard deviation with a cubic fit over time/part number.

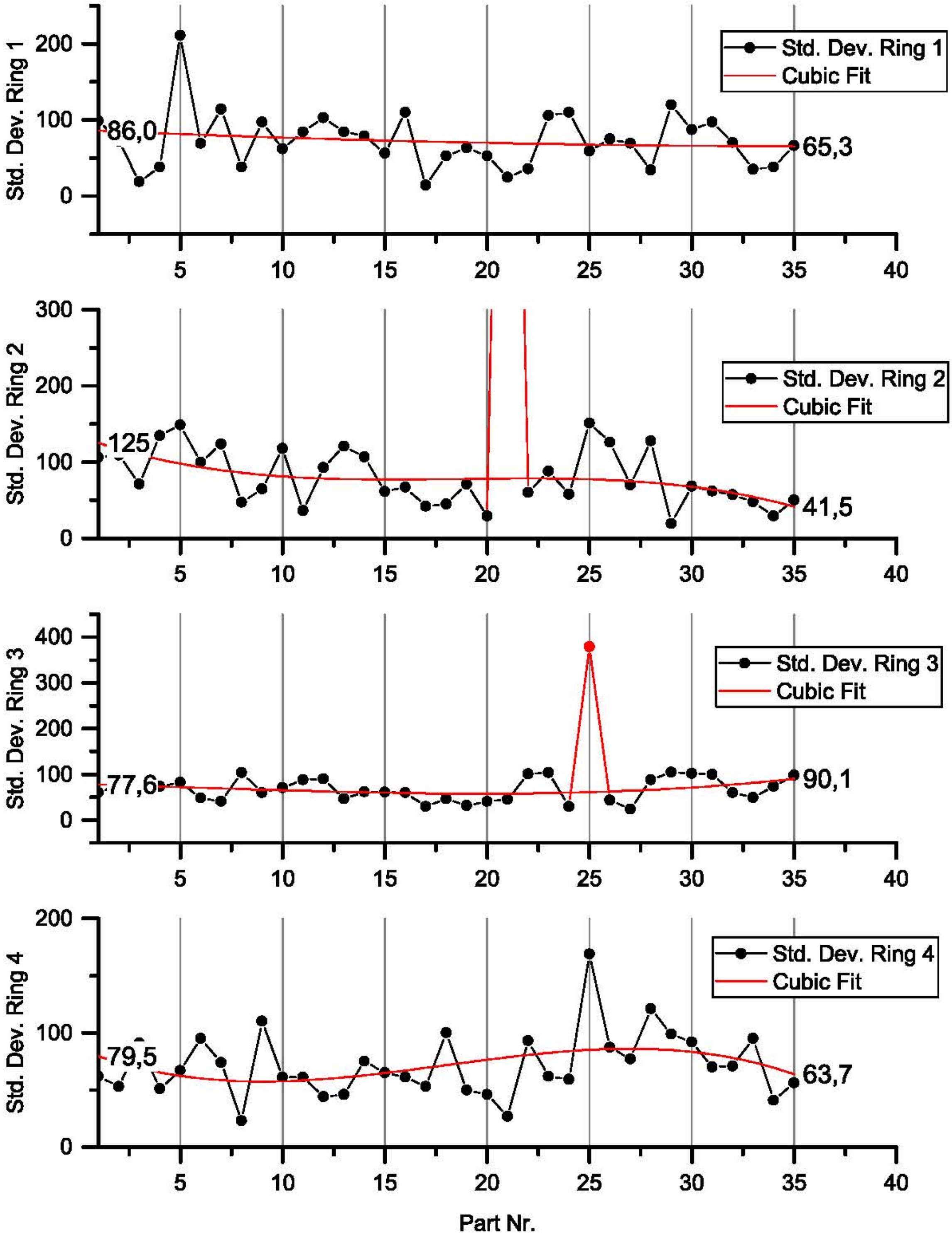


Figure 28: Results for weld line strength standard deviation, ring 1 to 4 during production run including 10 preceding startup shots.

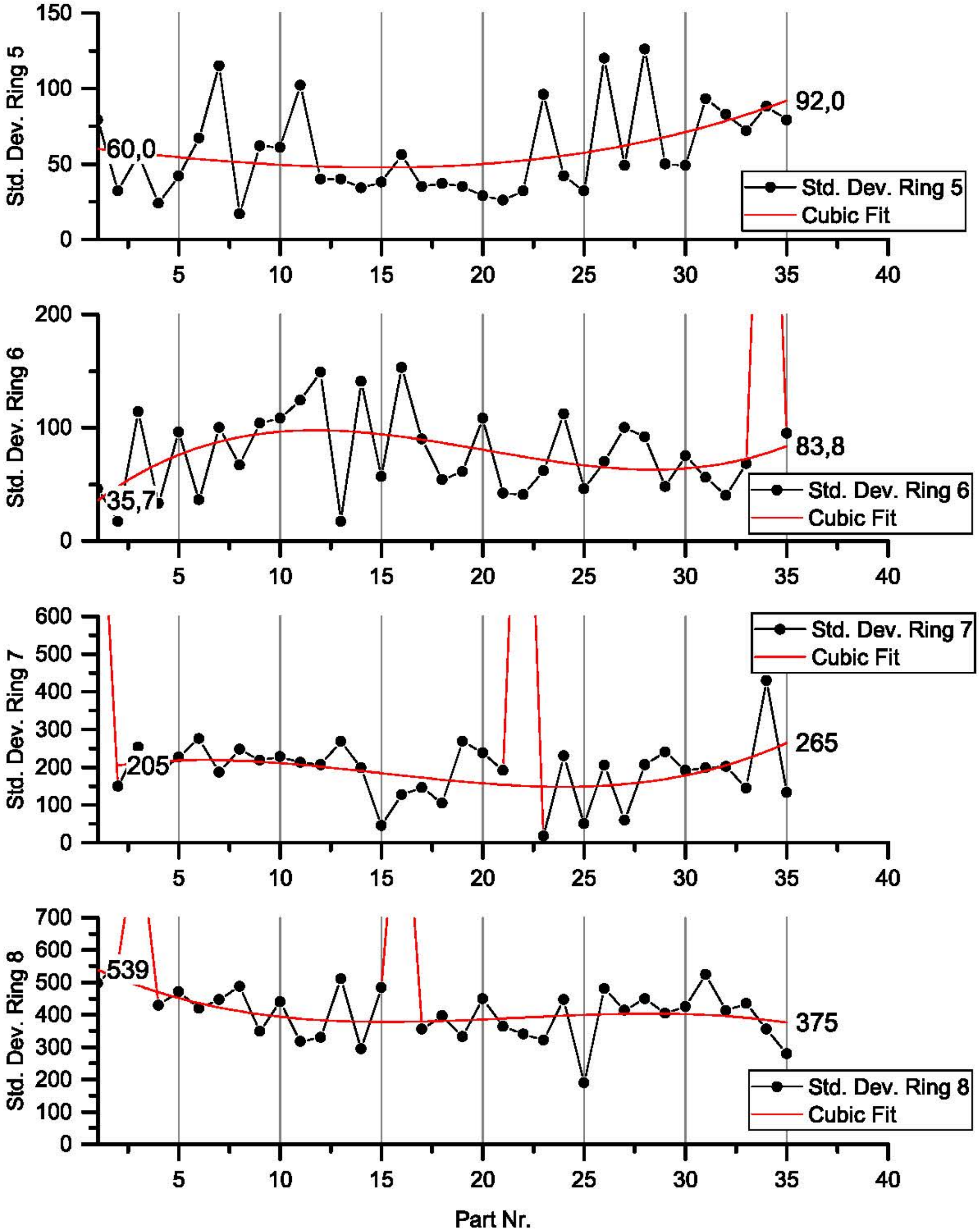


Figure 29: Results for weld line strength standard deviation, ring 5 to 8 during production run including 10 preceding startup shots.

No overall conclusion for all rings can be made. Some rings like ring 2 and 8 show a decrease in standard deviation over part number, while others like ring 6 and 7 show an increase. Taken into account that the standard deviation of the outer six rings is less than 5 % and of the inner two about 10 % the changes in standard deviation over time are mathematically between less than 1 % of the mean weld line strength of ring 3 and little over 5 % for ring 8. Taken into account that there is no overall drift of the standard deviation and the problems with testing the inner rings (see Chapter 4.2), this little change in standard deviation cannot be considered a significant change. Such a small change in standard deviation can be classified as a stable process.

4.4. Analysis of DoE

To determine a statistically significant change in weld line strength an analysis of variance (ANOVA) was performed using Tukey's method. For all statistics the software Minitab by Minitab Inc. and Excel by Microsoft were used. Taken from the Minitab StatGuide: "Tukey's method compares the means for each pair of factor levels using a family error rate to control the rate of type I error (concluding that there is a significant difference when there is none). The family error rate is the probability of making one or more type I errors for an entire set of comparisons." [45]

Setting 1 with medium switch-over and high injection rate was set as reference (Group A) for every ring. If a ring of another setting does not show up as Group A but Group B or Group C it is considered to have a statistically significant difference in weld line strength compared to the weld line strength of Setting 1. If a group shows two letters it can not be clearly allocated to a certain group and is part of both groups. To determine if the difference in weld line strength was either positive or negative the graphs in Figure 30 to Figure 34 were used.

Setting 2: Late switch-over and high injection rate.
Setting 2 does not show any specific changes in weld line strength or in standard deviation. The test results for significant changes in weld line strength can be found in Table 7. The measurement results can be seen in Figure 30.

Table 7: Grouping information using Tukey's method for Setting 2.

	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*	*Ring 8*
Group:	A	A	A	A	A	A	A	A

Setting 3: Early switch-over and high injection rate.
Also Setting 3 does not have significant changes compared to the production run. This suggests the switch-over point does not have an influence to weld line strength using MMIS. The test results for significant changes in weld line strength can be found in Table 8. The measurement results can be seen in Figure 31.

Table 8: Grouping information using Tukey's method for Setting 3.

	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*	*Ring 8*
Group:	A	A	A	A	A	A	A	A

Setting 4: Early switch-over and low injection rate.
Not all MMISs triggered and parts had to be removed by hand. The setting is considered not working.

Setting 5: Early switch-over and medium injection rate.
Not all MMISs triggered and parts had to be removed by hand. The setting is considered not working.

Setting 6: Late switch-over and low injection rate.
Setting 6 was on the very edge of a working production cycle. While the first injections triggered all MMISs successfully the fifth shot did not. Therefore producing parts with Setting 6 was stopped to prevent mold damage and cooling down of the mold because of the manual ejection of the part. The close to the edge character of this setting can also be seen in the test results. Ring 1, 4, 5 and 6 show significantly lower weld line strength. The test results for significant changes in weld line strength can be found in Table 9. The measurement results can be seen in Figure 32.

Table 9: Grouping information using Tukey's method for Setting 6.

	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*	*Ring 8*
Group:	C	A	A	C	B	B	A	A

Setting 7: Late switch-over and medium injection rate.
Setting 7 shows significantly lower weld line strength on ring 1 and 4. Those rings showed a weld line quality as bad as in Setting 6. Despite the fact that the setting worked it cannot be considered an option as the weld line quality must not decrease. The surface of the markings produced by the mold inserts showed major crinkles and were far away from the relatively smooth surface of the production run using Setting 1. The test results for significant changes in weld line strength can be found in Table 10. The measurement results can be seen in Figure 33.

Table 10: Grouping information using Tukey's method for Setting 7.

	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*	*Ring 8*
Group:	BC	A	A	B	A	AB	A	A

Setting 8: Medium switch-over and medium injection rate.
Setting 8 also shows weaker weld lines on ring 1 and 4 and is therefore considered not an option although all MMISs triggered. The surface of the markings produced by the mold inserts showed major crinkles and were far away from the relatively smooth surface of the production run using Setting 1. The test results for significant changes in weld line strength can be found in Table 11. The measurement results can be seen in Figure 34.

Table 11: Grouping information using Tukey's method for Setting 8.

	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*	*Ring 8*
Group:	B	A	A	B	A	A	A	A

Setting 9: medium switch-over and low injection rate.
Not all MMISs triggered and parts had to be removed by hand. The setting is considered not working.

As described in Chapter 3.5 to improve process stability the influence of a changed switch-over point and a change in injection speed was tested. The initial process setup (Setting 1) was developed during the R&D of the mold supported by simulations and polymer supplier suggestions. The following figures (Figure 30 to Figure 34) show how Setting 2 to 9 influence the weld line strength by comparing the results of the weld line tests of the specimens produced with Setting 2 to 9 (black line) to the mean weld line strength and standard deviation of Setting 1 (red line). The evaluation of Setting 1 can be found in Chapter 4.2 and is summarized in Table 6. The specimens of Setting 2 to 9 were produced directly after the 35 shots with Setting 1.

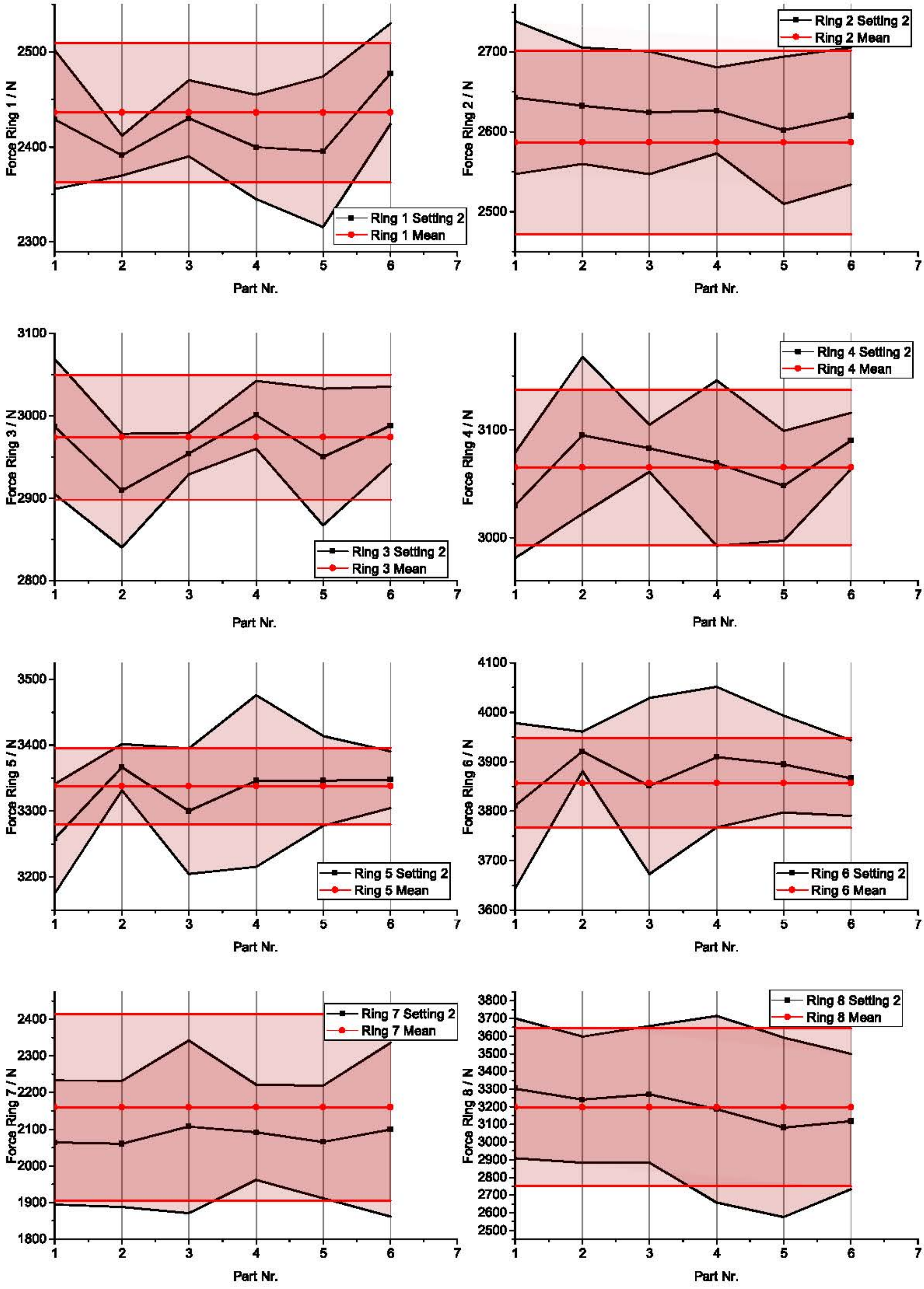


Figure 30: Results for weld line strength, ring 1-8, Setting 2.

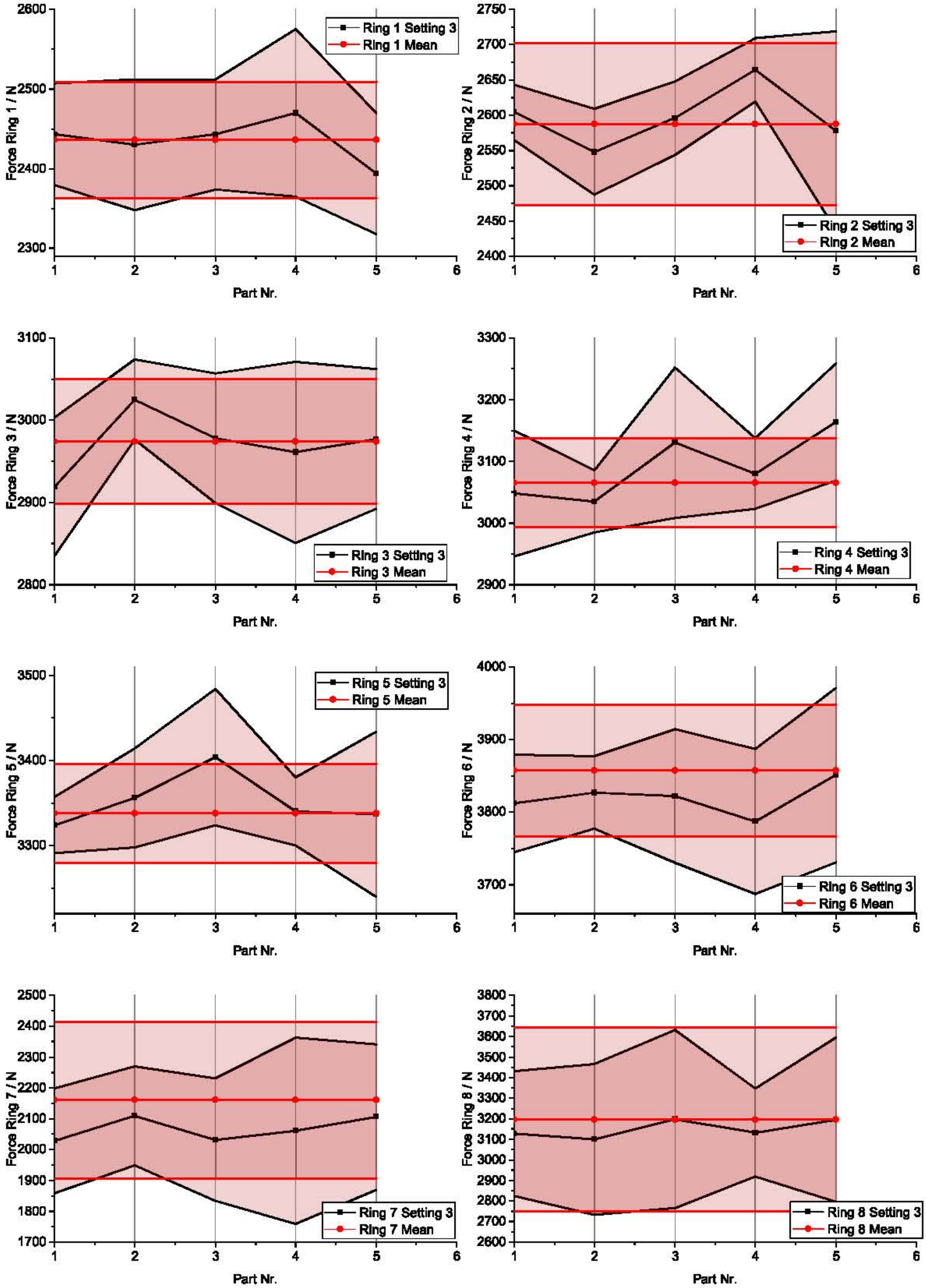


Figure 31: Results for weld line strength, ring 1-8, Setting 3.

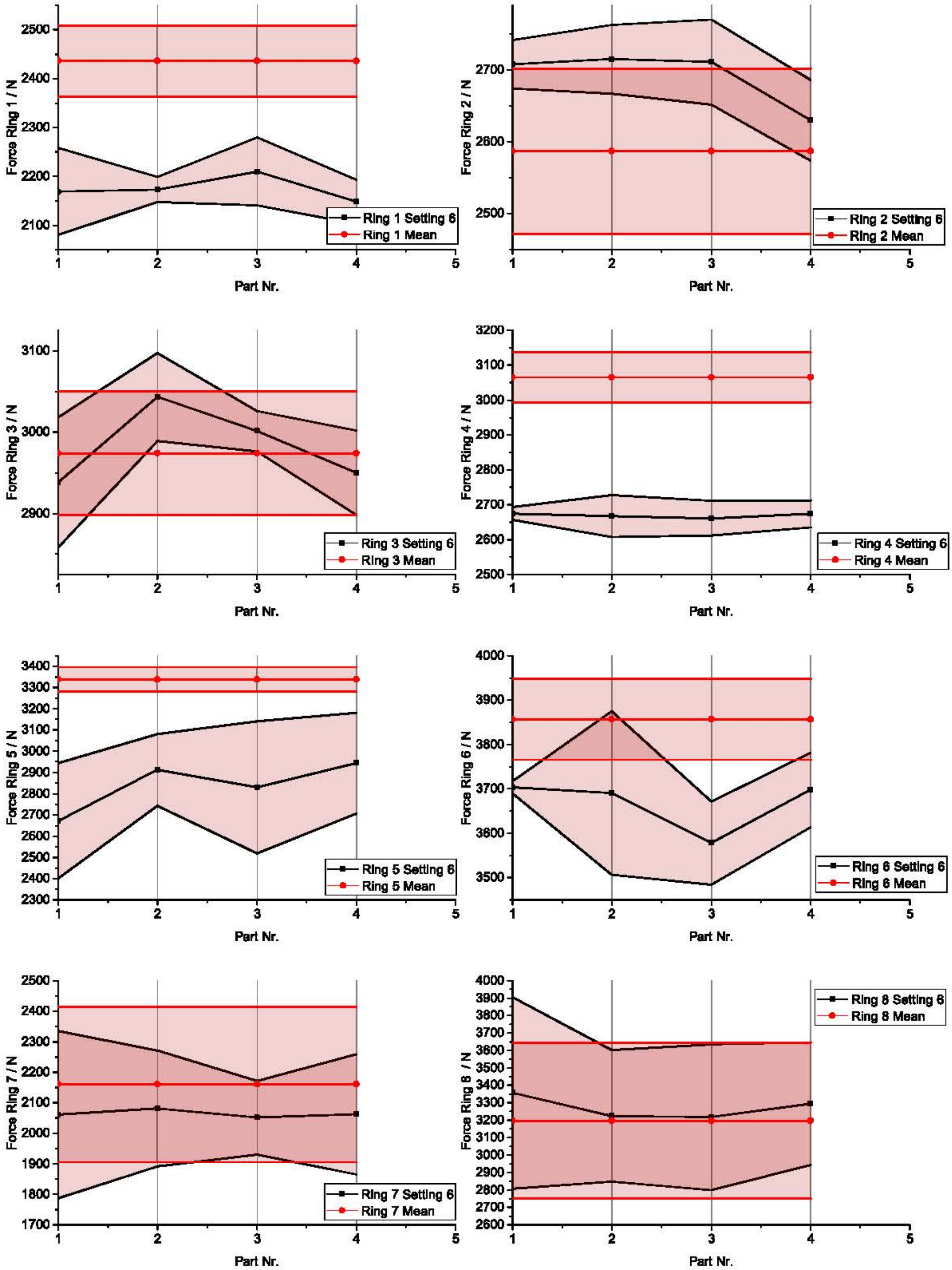


Figure 32: Results for weld line strength, ring 1-8, Setting 6.

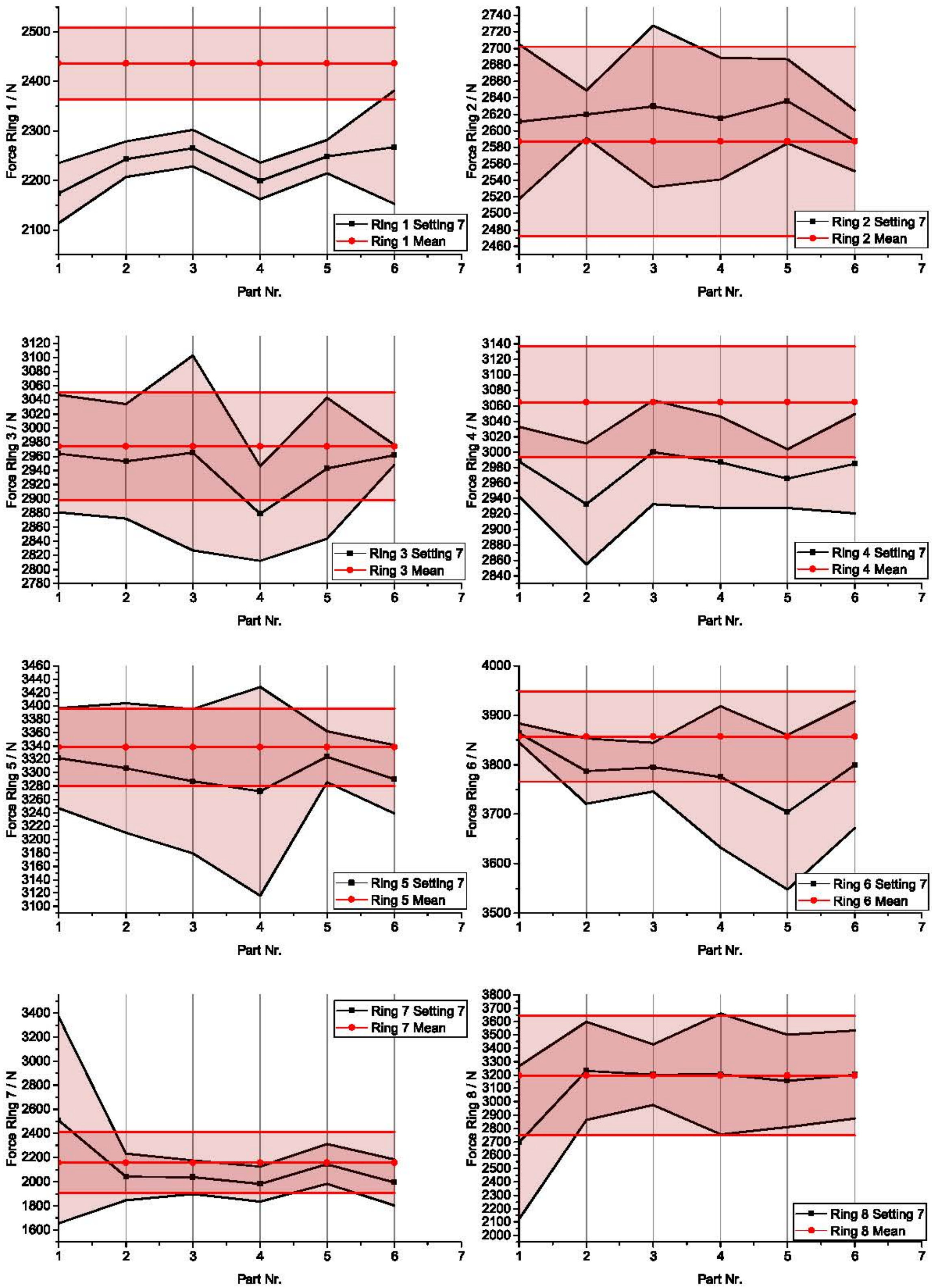


Figure 33: Results for weld line strength, ring 1-8, Setting 7.

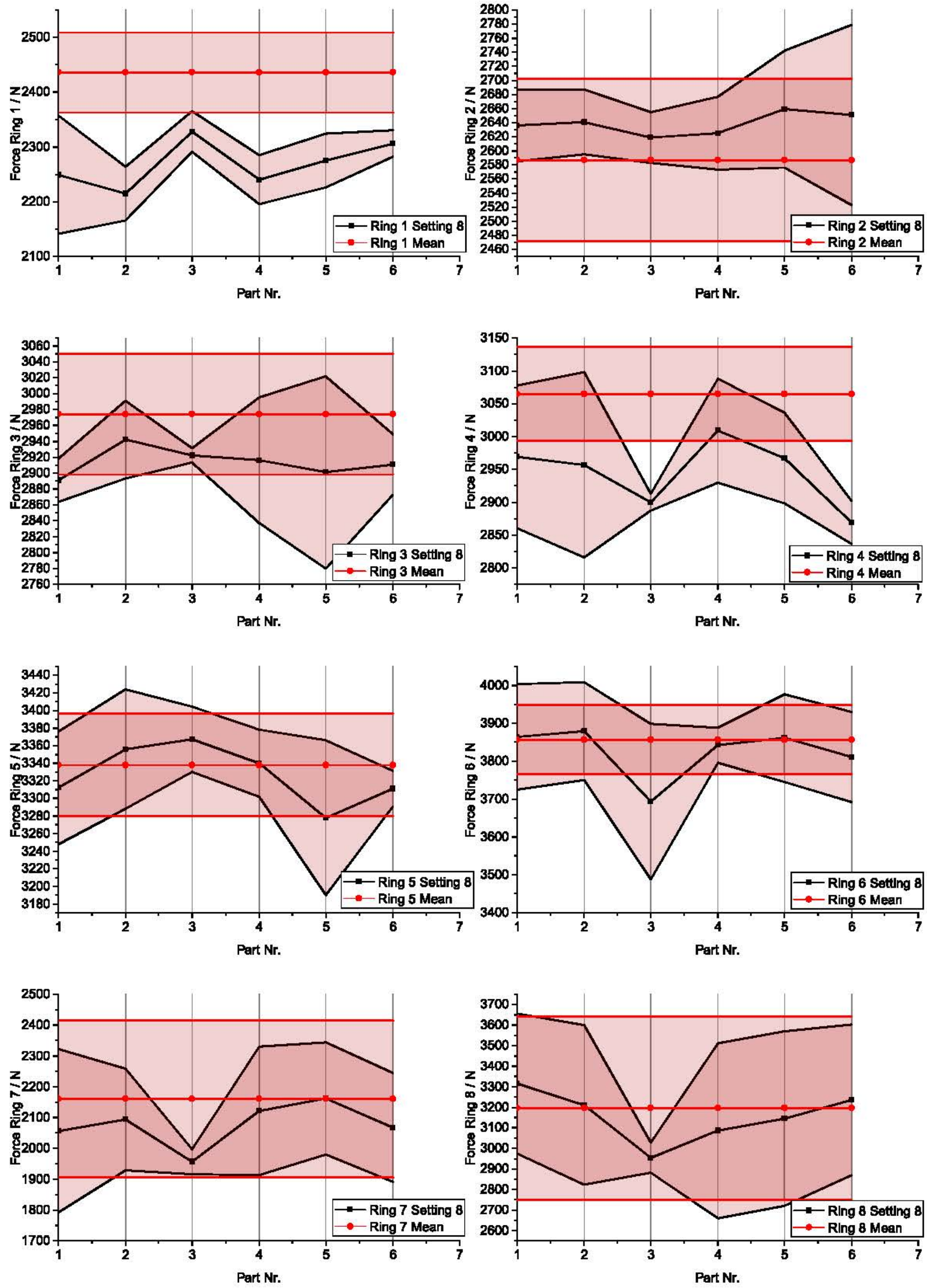


Figure 34: Results for weld line strength, ring 1-8, Setting 8.

Subsequently a comparison of the three values for the switch-over point from a) 54 cm^3 and b) 44 cm^3 to c) 34 cm^3 can be found. It is clearly visible in Figure 35 a) that the early switch-over point does only trigger the three inner rings which means there is not enough material in the cavity yet to reach 98 % cavity fill, especially when the cavity volume changes as more and more MMISs are triggered. Also a lot of sink marks can be seen. Figure 35 b) shows the switch-over point used in the production run. Although more MMISs triggered and less sink marks can be observed the switch-over is still not optimized whereas in c) all MMISs triggered which means the cavity volume does not change any more. By checking the parting surface and the parting line on the specimen it was ensured that the cavity was not overfed.

a) b) c)

Figure 35: Comparison of the three used switch-over points. a) 54 cm^3 and b) 44 cm^3 and c) 34 cm^3

4.5. Defining a "Good" Part

The purpose for every test station is to be able to determine if a certain criterion meets its requirements. If the criterion does meet its set value the specimen shall be defined as a "good" part, otherwise as a "bad" part. As the main criterion for the weld line tests the overall weld line strength until break was defined. It represents the proper working of the MMIS the best and provides the most information for the durability of the weld lines and therefore the sealing element. During prior testing Janko [31] found that sealing elements that broke in field tests and load tests showed a much lower weld line strength than parts that were performing well, although the loads in application are much more dynamic than the test situation with its comparable static conditions. A very good indicator for the parts' quality is the surface and the location of the broken weld lines. A well performing weld line shows a fracture layer which is almost perpendicular to the ring geometry just like a weld line would be if there would be no MMIS but with a very rough surface. A bad weld line breaks exactly along the MMIS with a very smooth surface as the two melt streams could not interact (see Chapter 4.1). With these two criteria force at break and break surface geometry/structure a good weld line can be determined. As the sealing element is as weak as its weakest weld line, a set of four out of eight weld lines per ring was tested to minimize the probability of undetected bad weld lines.

In Table 12 the set force limits for every ring of the respective sealing element based on the research done are listed. For all weld lines that showed less than 5 % standard deviation and shift in standard deviation the force limit was set 5 % below the average weld line strength of Setting 1 (startup and production run). For the two inner rings that showed more than 5 % standard deviation the limits were set individually to 15 % for ring 7 and 20 % for ring 8 below the settings of Setting 1.

Table 12: Set minimum force levels to define a good 261XP part.

261XP	Unit	Value
Ring 1	N	2310
Ring 2	N	2460
Ring 3	N	2830
Ring 4	N	2910
Ring 5	N	3170
Ring 6	N	3660
Ring 7	N	1940
Ring 8	N	2560

As a second criterion for a good weld line the surface of the markings produced by the MMIS can be used. A good weld line normally shows no or very small crinkles whereas mold inserts that barely triggered mostly show a considerably rougher surface (Figure 36). As this is a very quick optical test but subjective, it can be taken as an additional pre-selection.

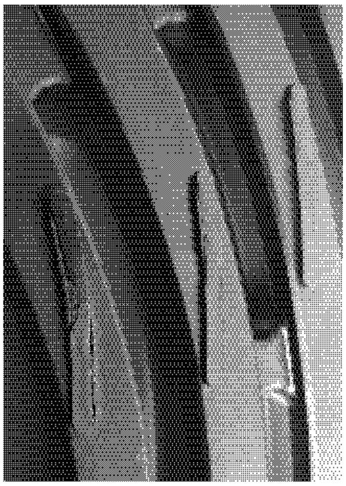


Figure 36: Example for a weld line marking with a bad surface quality taken from a Setting 6 shot.

4.6. Conclusion

The injection rate turned out to be the more important of the two investigated process parameters. All settings with a high injection rate showed good weld line quality. It can be stated that the time elapsed from start of injection to the point where the melt front hits the obstacles and the time that elapses until the mold is finally completely filled and the pressure can trigger the MMISs is the most important factor as the elapsed time directly affects the temperature of the melt, the mold surface temperature and the temperature of the obstacles. The switch-over point seems to play an assisting role if the injection speed is too low. For example, comparing Setting 4 to Setting 6: Setting 4 was not working, by delaying the switch-over point it was at least possible to get the low injection speed working. The same is valid for Setting 5 and Setting 7 or Setting 8. Setting 7 and Setting 8 did not produce good parts but at least the later switch-over triggered all MMISs. Figure 37 gives an overview of the DoE and its working settings.

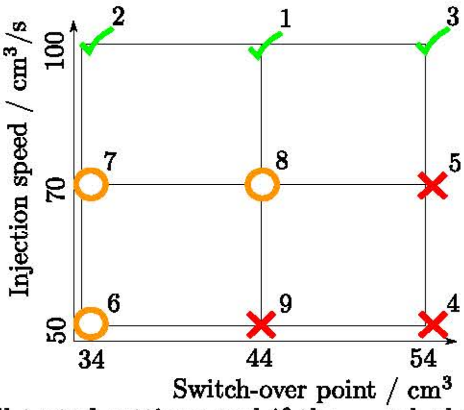


Figure 37: Overview of all tested settings and if they worked (green check mark), worked but showed inferior results (orange circle) or if they could not be run for the production of specimens (red cross). The number next to each symbol represents the setting number.

Summarizing all experiments it seems that everything comes down to melt viscosity. The lower the viscosity of the polymer is during filling and especially at the moment of triggering the MMIS the better. To achieve low viscosity in the moment of triggering the MMIS, the melt and mold temperature or the injection speed can be raised. As described in Chapter 3.5 the temperatures have already been raised or caused other problems during production and are therefore no option any more. Raising injection speed would be generally an option but not with the used injection molding machine as it was already at its pressure limit. Also polymer and filler degradation caused by very high injection speeds had to be taken into account.

One solution could be to not heat the mold as a whole but only the obstacles and/or the area of the MMIS to heat up the melt during its standby at the obstacle waiting for the switch-over to hold pressure. This could be done during mold open time. The mold open time in the process is relatively long to allow the mold to cool down a little especially in the center areas. With electric heaters or induction the small obstacles could be heated up fairly quickly which might help to use lower injection speeds. Another option could be changing the barrel of the injection molding machine to a smaller diameter resulting in a higher possible injection pressure leading to higher possible injection speeds.

5. Resume

To be able to produce injection molded parts with uniform quality in a changing process environment process parameters have to be adjusted. These process parameters are either fixed for some reason or can be adjusted in a certain range [31]. The aim of this thesis was to verify the influence of a changing switch-over point and to determine the influence of a changed injection speed on the successful use of a movable mold insert system (Chapter 2.6.2). Most other considerable factors in this process which have an impact on the functionality of the MMIS and the produced weld line quality of this system were fixed.

To test the impact of those factors a new test station was designed and manufactured (Chapter 3.4). The test station consists of a hand press, a base unit and a changeable carrier accompanied by an evaluation unit. It is capable of testing several types of valve plates in a quick and easy way. Two aspects were investigated during the testing. First, is the production process stable and second, can the injection speed be lowered and does the switch-over point influence the results. Process stability was examined by taking a look on shifts in weld line strength and changes in standard deviation over time. Even with a significantly changing mold temperature no significant trends or shifts could be found (Chapter 4).

The weld line strength was tested by tracking force over displacement of the weld line area until failing. The results showed once all movable mold inserts were triggered reliably there was almost no change in weld line strength detectable regardless of which injection speeds and switch-over points were used. However, some settings were tested which showed a barely working character. These settings showed an unsatisfactory weld line strength although the produced specimen had triggered all movable mold inserts. The settings were able to produce parts but did not reliably trigger all mold inserts. To identify such settings that trigger all mold inserts but still show a bad weld line quality the surface of the obstacle markings can be used as a quality criterion (Chapter 4.5). These settings can be used as the low end setting for future testing but cannot be used for a production run.

As the designed test station worked properly and showed no major flaws additional carriers for other types of valve plates will be designed and manufactured. With all carriers manufactured the test station will be able to test eight different types of plates with minimal setup time. For every plate type a production run has to be analyzed to determine the weld line characteristics of each type. Subsequently, a DoE has to be made and tested. It is suggested to use smaller parameter steps than those that were applied in this thesis.

Because of the close to the edge character of Setting 6 (Chapter 4.4)it is suggested to design a new experiment with only changing the injection speed in several steps down to the injection speed of Setting 6 but leaving the switch-over at the latest switch-over point. This would keep expenses to a minimum and still gives information about the lowest possible injection speed for the 261XP process.

For the currently used production process it is advised to set the switch-over point to the latest setting of $34\,cm^3$ and leaving the injection speed at the used setting of $100\,cm^3/s$. For future investments in the injection molding machine a smaller barrel and screw should be considered.

6. References

[1] H. Becker, G. Fischer, and U. Müller. Gegentakt-Spritzgießen technischer Formteile: Auf dem Weg zu spritzgegossenen Composites. 83(3):165–169, 1993.

[2] S. Bensason, E. V. Stepanov, S. Chum, A. Hiltner, and E. Baer. Deformation of Elastomeric Ethylene–Octene Copolymers. *Macromolecules*, 30(8):2436–2444, 1997.

[3] John Bown. *Injection moulding of plastic components: A guide to efficiency, fault diagnosis, and cure.* McGraw-Hill Book Co, London and New York, 1979.

[4] Tao C. Chang and Ernest Faison. Optimization of Weld Line Quality in Injection Molding- Using an Experimental Design Approach. *Journal of Injection Molding Technology*, 3(2):61–66, 1999.

[5] Tao C. Chang and Ernest Faison. Shrinkage Behavior and Optimization of Injection Molded Parts Studied by the Taguchi Method. *Polymer Engineering and Science*, 41(5):703–710, 2001.

[6] Shia-Chung Chen, Yi Chang, Yeon-Pun Chang, Yen-Chen Chen, and Chia-Yen Tseng. Effect of Cavity Surface Coating on Mold Temperature Variation and the Quality of Injection Molded Parts. *International Communications in Heat and Mass Transfer*, 36(10):1030–1035, 2009.

[7] Shia-Chung Chen, Wen-Ren Jong, and Jen-An Chang. Dynamic Mold Murface Temperature Control Using Induction Heating and its Effects on the Surface Appearance of Weld Lines. *Journal of Applied Polymer Science*, 101(2):1174–1180, 2006.

[8] P. Cloud, F. McDowel, and S. Gerakaris. Reinforced Thermoplastics: Understanding Weld-Line Integrity. *Plastics Technology*, 22:48–51, 1976.

[9] R. M. Criens and H. G. Moslé. On the Influence of Knit-lines on the Mechanical Behavior of Injection Molded Structural Elements. *ANTEC*, pages 22–24, 1982.

[10] R. M. Criens and H. G. Moslé. The Influence of Knit-lines on the Tensile Properties of Injection Molded Parts. *Polymer Engineering and Science*, 23(10):591–596, 1983.

[11] Hans Domininghaus, Peter Elsner, Peter Eyerer, and Thomas Hirth. *Kunststoffe: Eigenschaften und Anwendungen ; mit 275 Tabellen.* VDI-Buch. Springer, Heidelberg [u.a], 8 edition, 2012.

[12] Gottfried W. Ehrenstein. *Polymer-Werkstoffe: Struktur - Eigenschaften - Anwendung ; mit 22 Tabellen.* Studientexte Kunststofftechnik. Hanser, München and Wien, 2 edition, 1999.

[13] Gottfried W. Ehrenstein. *Resistance and stability of polymers.* Hanser, München and Cincinnati, Ohio, 2013.

[14] Gottfried W. Ehrenstein and R. P. Theriault. *Polymeric materials: Structure, properties, applications.* Hanser and Hanser Gardner Publications, Munich and Cincinnati, OH, 2001.

[15] Peter Elsner, Peter Eyerer, and Thomas Hirth. *Polymer Engineering: Technologien und Praxis.* VDI-Buch. Springer, Dordrecht, 2008.

[16] Burak Erman and James. E. Mark. *Structures and Properties of Rubberlike Networks.* Oxford University Press, New York, 1997.

[17] S. Fellahi, A. Meddad, B. Fisa, and B. D. Favis. Weldlines in Injection-Molded Parts: A Review. *Advances in Polymer Technology*, 14(3):169–195, 1995.

[18] B. Fisa and M. Rahmani. Weldline Strength in Injection Molded Glass Fiber-reinforced Polypropylene. *Polymer Engineering and Science*, 31(18):1330–1336, 1991.

[19] Jerry M. Fischer. *Handbook of Molded Part Shrinkage and Warpage.* PDL handbook series. William Andrew, Waltham, Mass., 2 edition, 2013.

[20] Garren Gardner and Carole Cross. The Effect of a Heated Core Pin on the Weld Strength of PP. *Plastic Engineering*, Vol. 49(2):29–32, 1993.

[21] Wolfgang Grellmann, Sabine Seidler, and V. Alstädt. *Polymer Testing.* Hanser Publishers, Munich, 2 edition, 2013.

[22] Peter Gummert and Karl-August Reckling. *Mechanik.* Vieweg, Braunschweig, 3 edition, 1994.

[23] L. Gutjahr and H. Becker. Herstellen technischer Formteile mit dem Gegentakt-Spritzgießverfahren. *Kunststoffe*, 79(11):1108–1112, 1989.

[24] L. Gutjahr and W. Nesch. Patent: Verfahren und Vorrichtung zum Spritzgießen von Spritzgußteilen aus plastifizierbarem Material, insbesondere aus plastifizierbaren flüssigkristall-Polymeren. Patent Number: EP0339184 B1, 1995.

[25] M. Häberlein. Kunststofftechnologie- Vorlesungsskript: 5.2.2 Spritzgussform, 2012.

[26] E. M. Hagerman. Weld-Line Fracture in Molded Parts. *Plastic Engineering*, 29(10):67–69, 1973.

[27] H. Hamada, Z. Maekawa, T. Horino, K. Lee, and K. Tomari. Improvement of Weld Line Strength in Injection Molded FRTP Articles. *International Polymer Processing*, 2(3-4):131–136, 1988.

[28] S. Y. Hobbs. Some Observations on the Morphology and Fracture Characteristics of Knit-lines. *Polymer Engineering and Science*, 14(9):621–626, 1974.

[29] Hoerbiger Marketing. Verwendung von Bildmaterial: oral, 13.09.2016.

[30] Marian Janko. *Optimization of the Injection Molding Technology for Profiled High-performance Thermoplastic Sealing Elements.* PhD. Thesis, Montanuniversitaet Leoben, Leoben, April, 2015.

[31] K. M. B. Jansen, D. J. van Dijk, and M. H. Husselman. Effect of Processing Conditions on Shrinkage in Injection Molding. *Polymer Engineering and Science*, 38(5):838–846, 1998.

[32] A. Kaufmann. *Geometrical Modification of Weld Lines for High-performance Plastics in Injection Molding.* Master Thesis, Montanuniversitaet Leoben, Leoben, June 2013.

[33] Yutaka Kobayashi, Gensei Teramoto, and Toshitaka Kanai. The Unique Flow of Polypropylene at the Weldline Behind an Obstacle in Injection Molding. *Polymer Engineering and Science*, 51(3):526–531, 2011.

[34] Ines Kühnert. *Grenzflächen beim Mehrkunststoffspritzgießen: Techn. Univ., Diss–Chemnitz, 2005*, volume 1 of *Schriftenreihe Kunststoffe*. FKTU, Chemnitz, [elektronische ressource] edition, 2005.

[35] Lucyshyn T., Janko M., Schmid M., and Holzer C. Poster Presentation: Interaction Between Injection Molding Parameters, Fiber Orientation and Warpage in Carbon Fiber-reinforced Polyphenylene Sulfide (PPS) Valve Plates. 2013. In *International Conference of the Polymer Processing Society*, volume 29.

[36] H.-C. Ludwig, G. Fischer, and H. Becker. Quantitative Comparison of Morphology and Fibre Orientation in Push-Pull Processed and Conventional Injection-Moulded Parts. *Composites Science and Technology*, 53:235–239, 1995.

[37] S. C. Malguarnera and A. Manisali. The Effects of Processing Parameters on the Tensile Properties of Weldlines in Injection Molded Thermoplastics. *Polymer Engineering and Science*, 21(10):586–593, 1981.

[38] S. C. Malguarnera and D. C. Riggs. Weld Line Morphology in Injection-Molded General Purpose and High Impact Polystyrene. *Polymer-Plastics Technology and Engineering*, 17(2):193–209, 1981.

[39] Salvatore C. Malguarnera. Weld Lines in Polymer Processing. *Polymer-Plastics Technology and Engineering*, 18(1):1–45, 1982.

[40] Wilhelm Matek, Dieter Muhs, and Hermann Roloff. *Maschinenelemente: Normung, Berechnung, Gestaltung*. Vieweg, Braunschweig [u.a.], 20 edition, 2011.

[41] A. Meddad and B. Fisa. Weldline Strength in Flass Fiber-reinforced Polyamide 66. *Polymer Engineering and Science*, 35(11):893–901, 1995.

[42] G. Menges and T. Schacht. Einfluss der Verarbeitungsparameter auf die mechanischen Eigenschaften von Bindenähten. *Kunststoffberater*, 54(4):54–57, 1988.

[43] G. Mennig. Zum Einfluss des Molekulargewichts auf die makroskopische Grenzfläche Bindenaht. *Angewandte Makromolekulare Chemie*, 185(1):179–188, 1991.

[44] Minitab Inc. Minitab (Minitab StatGuide), 2012.

[45] H. G. Moslé, R. M. Criens, and H. Dick. On the Strength of Knit-lines in Injection Molded Parts. *ANTEC*, pages 772–776, 1984.

[46] Tim A. Osswald. *International Plastics Handbook: The resource for plastics engineers*. Hanser, Munich and Cincinnati, 1 edition, 2006.

[47] Babur Ozcelik, Emel Kuram, and M. Mustafa Topal. Investigation of the effects of obstacle geometries and injection molding parameters on weld line strength using experimental and finite element methods in plastic injection molding. *International Communications in Heat and Mass Transfer*, 39(2):275–281, 2012.

[48] Parametric Technology GmbH. CAD software.

[49] S. Patcharaphun. Investigation on Weldline Strength of Short-Glass-Fiber Reinforced Polycarbonate Manufactured through Push-Pull-Processing Technique. *Journal of Reinforced Plastics and Composites*, 25(4):421–435, 2005.

[50] W. Rose. Fluid-Fluid Interfaces in Steady Motion. *Nature*, 191(4785):242–243, 1961.

[51] Joseph C. Salamone. *Concise polymeric materials encyclopedia.* CRC Press, Boca Raton, 1999.

[52] B. Sanschagrin, R. Gauvin, B. Fisa, and T. Vu-Khanh. Weldlines in Injection Molded Polypropylene: Effect of Filler Shape. *Journal of Reinforced Plastics and Composites*, 9(2):194–208, 1990.

[53] Friedrich Rudolf Schwarzl. *Polymermechanik: Struktur und mechanisches Verhalten von Polymeren.* Springer Berlin Heidelberg, Berlin, Heidelberg, 1990.

[54] R. Seldén. Effect of Processing on Weld Line Strength in Five Thermoplastics. *Polymer Engineering and Science*, 37(1):205–218, 1997.

[55] Zehev Tadmor and Costas G. Gogos. *Principles of polymer processing.* Wiley-Interscience, Hoboken, N.J., 2 edition, 2006.

[56] P. A. Templeton. Strength Predictions of Injection Molding Compounds. *Journal of Reinforced Plastics and Composites*, 9(3):210–225, 1990.

[57] Yves Termonia and Paul Smith. Kinetic Model for Tensile Deformation of Polymers. *Macromolecules*, 20(4):835–838, 1987.

[58] K. Tomari, T. Harada, Z. Maekawa, H. Hamada, M. Iwamoto, and A. Ukai. Fracture Toughness of Weldlines in Thermoplastic Injection Molding. *Polymer Engineering and Science*, 33(15):996–1001, 1993.

[59] K. Tomari, S. Tonogai, T. Harada, H. Hamada, K. Lee, T. Morii, and Z. Maekawa. The V-notch at Weldlines in Polystyrene Injection Moldings. *Polymer Engineering and Science*, 30(15):931–936, 1990.

[60] Kiyotaka Tomari, Hiroki Takashima, and Hiroyuki Hamada. Improvement of Weldline Strength of Fiber Reinforced Polycarbonate Injection Molded Articles Using Simultaneous Composite Injection Molding. *Advances in Polymer Technology*, 14(1):25–34, 1995.

[61] Guilong Wang, Guoqun Zhao, Huiping Li, and Yanjin Guan. Research of thermal response simulation and mold structure optimization for rapid heat cycle molding processes, respectively, with steam heating and electric heating. *Materials & Design*, 31(1):382–395, 2010.

[62] Guilong Wang, Guoqun Zhao, and Xiaoxin Wang. Effects of Cavity Surface Temperature on Mechanical Properties of Specimens with and without a Weldline in Rapid Heat Cycle Molding. *Materials & Design*, 46:457–472, 2013.

[63] Cheng-Hsien Wu and Wan-Jung Liang. Effects of Geometry and Injection Molding Parameters on Weldline Strength. *Polymer Engineering and Science*, 45(7):1021–1030, 2005.

[64] D. Zorn. Filling simulation and pressure distribution, 28.1.2017.

List of Figures

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A. Sensor Data Sheets

Prüf- und Kalibrierprotokoll
Test- and Calibration Certificate

Kraftsensor für Handhebelpressen
Load cell for manual toggle presses

Typ	/ *Type*		: **8451-6020**
Serien-Nr.	/ *Serial no.*		: **453775**
Qualitätsprüfungen	/ ***Quality Inspections***		
Nennkraft	/ *Nominal Force*	F_{nom}	: **0 ... 20 kN**
Fehlergrenzen (Zusammengesetzter Fehler) Summe der Fehler aus Linearitätsabweichung, Relative Umkehrspanne und Reproduzierbarkeit	/ *Accuracy (Combined value)* / *Combined value for nonlinearity, / repeatability and hysteresis.*	f_{comb}	: **≤ ± 1,0 % v.E. / FS**
Kalibriert in	/ *Calibration for*		: **Druckrichtung / *Compression***
Maximale Gebrauchskraft	/ *Maximum Force, Operating*	F_G	: **150 % v.E. / FS**
Integrierter Überlastschutz bis	/ *Integrated overload protection*	F_L	: **30 kN**
Schutzart (IP-Code)	/ *Degrees of protection (IP-Code)*		: **IP 67** nach / *according to* **EN 60 529**
Referenzspeisespannung	/ *Reference Excitation*	U_{Ref}	: **10,0 V_{DC}**
Ausgangssignal (Kennwert) Ausgangssignal beim Messbereichsendwert bei tariertem Nullpunkt	/ *Output signal (Sensitivity)* / *Output signal at measuring range* / *with balanced zero.*	C	: **1,6272 mV/V**
Nullsignal ohne Einbauteile	/ *Zero Output* / *without fitting parts*	S_0	: **-0,0108 mV/V**
Eingangswiderstand	/ *Input Impedance*	R_e	: **377,82 Ω**
Ausgangswiderstand	/ *Output Impedance*	R_a	: **352,39 Ω**
Isolationswiderstand	/ *Insulation Resistance*	R_{is}	: **≥ 30 MΩ @ 45 V**
Kalibriersprung (bei unbelastetem Aufnehmer)	/ *Shunt Cal Factor (without any load)*	C_{Shunt}	: **1,1021 mV/V**
Kalibrierwiderstand Ein Kalibrierwiderstand R_{Shunt}, zwischen -Speisung und -Ausgangssignal, erzeugt bei tariertem Nullpunkt, den angegebenen Kalibriersprung C_{Shunt}.	/ *Calibration Resistor (Shunt)* / *A Calibration Resistor R_{Shunt} connected* / *across -excitation and -output produce* / *this Shunt Cal Factor C_{Shunt}* / *with balanced Zero Output.*	R_{Shunt}	: **80 kΩ**
Validiert nach Prüfanweisung	/ *Validated according to Inspection Instruction*		: **1219**

Die Rückführbarkeit der verwendeten Sekundärnormale auf nationale bzw. internationale Normale, entsprechend der Normenreihe DIN EN ISO 9000 ff, ist über Kalibrier- oder Eichscheine gewährleistet. Die verwendeten Normale sind auf Kalibrierlaboratorien rückführbar, die nach ISO/IEC 17025 akkreditiert sind.

The traceability of the used secondary standards to the national respectively international standards, according to DIN EN ISO 9000 ff, is guaranteed by Calibration certificate. The used standards are traceable to calibration laboratories, which are accredited to ISO/IEC 17025.

Das Produkt erfüllt die im Datenblatt angegebenen Spezifikationen.
The device performs the specifications mentioned in the data sheet.

Anschlussbelegung: 4-Leiter unverstärkt
Wiring Code: 4-Wire unamplified

Signal	/ ***Signal***	**Farbe**	/ ***Color***	**Belegung / *mode*** 99004	99007	**Steckertyp / *Connector model*** 9941	9900-V209	9900-V280	91615	9900-V506	9900-V106
+ Speisung	/ *Excitation*	weiß	/ *white*	——	——	C/D	1/2	8	20	5	11
- Speisung	/ *Excitation*	braun	/ *brown*	——	——	A/B	4/5	1	3	6	9
+ Ausgangssignal	/ *Output*	gelb	/ *yellow*	——		G	6	11	1	1	13
- Ausgangssignal	/ *Output*	grün	/ *green*	——		F	9	12	2	3	14
Schirm	/ *Shield*	blank	/ *not isolated*	——	——	Gehäuse/case	Gehäuse/case	13	3	6	9

☑ **99004** : Steckermontage: Standard-Belegung: Ausgangssignal in Vorzugsrichtung positiv / *Plug assembly: Normal mode: Output signal in preferred direction is positive*

☑ **9900-V209** : D-Sub-Stecker 9-polig (metallisiertes Plastikgehäuse) / *D-Sub-Connector 9-pin (Metalized plastic backshells)*
9900-V210 : Identisch mit 9900-V209 (45° Kabelabgang) / *Identically to 9900-V209 (45° cable outlet)*

Nach der vorliegenden Erfahrung ist es empfehlenswert, das Produkt im Abstand von etwa 24 Monaten neu zu kalibrieren. / *According to our experience it is recommended to recalibrate this product in intervals of 24 months.*

Raumtemperatur / *Ambient temperature*: 22 °C ± 2 K   Rel. Feuchte / *Relative humidity*: 50 % ± 20 %

Prüfdatum / *Test Date* : **10.02.16**   Prüfer / *Inspector* : **M. Fratric**

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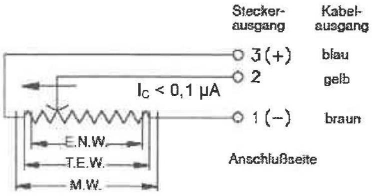
http://www.burster.de http://www.burster.com e-mail: info@burster.de

Prüf- und Kalibrierprotokoll
Test- and Calibration Certificate



Potentiometrischer Wegsensor

Potentiometric displacement sensor

Typ	/ *Type*	: **8711-50**
Serien-Nr.	/ *Serial no.*	: **87154200196**

Messweg (Elektrischer Nutzweg)	/ *Range (useful electrical stroke)*	*E.N.W.*	: **50 mm** **+ 3 / - 0 mm**
Theoretischer elektrischer Weg	/ *Theoretical electrical stroke*	*T.E.W.*	: **E.N.W + 1 mm ± 1 mm**
Mechanischer Weg	/ *Mechanical stroke*	*M.W.*	: **E.N.W + 5 mm**
Maximal zulässige Speisespannung	/ *Maximum applicable voltage*	U_{max}	: **≤ 50 V_{DC}**
Anschlusswiderstand	/ *Connecting resistance*	$R_{E.N.W.}$	: **5 kΩ ± 20 %**
Empfohlener Strom im Schleiferkreis	/ *Recommended cursor current*	I_C	: **< 0,1 µA**
Fehlergrenze (Linearitätsabweichung)	/ *Error limit (Independent linearity)*	f_{lin}	: **± 0,1 % v.E. / FS** innerhalb E.N.W / *within E.N.W.*
Isolationswiderstand	/ *Electrical isolaton*	R_{iso}	: **> 100 MΩ**
Arbeitstemperaturbereich	/ *Operating Temperature range*	t_A	: **-30 ... 100 °C**
Temperaturkoeffizient	/ *Temperature Coefficient*	*TK*	: **< 1,5 ppm/K**
Verstellgeschwindigkeit	/ *Displacement speed*		: **≤ 10 m/s**
Schutzart (nach)	/ *Grade of Protection (according to)*		: **IP40** (DIN VDE 0470 / EN 60 529 / IEC 529)
Validiert nach Prüfanweisung	/ *Validated according to Inspection Instruction*		: **417**

Die Rückführbarkeit der verwendeten Sekundärnormale auf nationale bzw. internationale Normale, entsprechend der Normenreihe DIN EN ISO 9000 ff, ist über Kalibrier- oder Eichscheine gewährleistet. Die verwendeten Normale sind auf Kalibrierlaboratorien rückführbar, die nach ISO/IEC 17025 akkreditiert sind.

The traceability of the used secondary standards to the national respectively international standards, according to DIN EN ISO 9000 ff, is guaranteed by Calibration certificate. The used standards are traceable to calibration laboratories, which are accredited to ISO/IEC 17025.

Das Produkt erfüllt die im Datenblatt angegebenen Spezifikationen.
The device performs the specifications mentioned in the data sheet.

Nach der vorliegenden Erfahrung ist es empfehlenswert, das Produkt im Abstand von etwa 24 Monaten neu zu kalibrieren. / *According to our experience it is recommended to recalibrate this product in intervals of 24 months.*

Anschlussbelegung: **Belegung / *mode*** **Steckertyp / *Connector model*** **Typ: 9180 9181**

Wiring Code: **Signal**	**/ *Signal***	**Farbe / *Color***	99004	99007	9941	9900-V209	9970	91615	9900-V106	9900-V280	9900-V506	9900-V506
+ Speisung	/ *Excitation*	blau / *blue*	——	╲╱	C/D	1/2	1/2	20	11	2	5	5
- Speisung /Signal	/ *Excitation*	braun / *brown*	——	╱╲	A/B/F	4/5/9	4/5/6	3/2	9/13	1/12	6/3	6/3
+ Ausgangssignal	/ *Output*	gelb / *yellow*	——	——	G	6	3	1	14	11	2	1

☑ **99004** : Nullsignal bei ausgefahrener Schubstange / *Zero signal with control rod end position out*

☑ **9900-V209** : D-Sub-Stecker 9-polig (metallisiertes Plastikgehäuse) / *D-Sub-Connector 9-pin (Metalized plastic backshells)*
9900-V210 : Identisch mit 9900-V209 (45° Kabelabgang) / *Identically to 9900-V209 (45° cable outlet)*

Raumtemperatur / *Ambient temperature*: 23 °C ± 3 K Rel. Feuchte / *Relative humidity*: 50 % ± 20 %

Datum / *Date* : **15.10.15**

Protokoll erstellt durch / *Certificate written by* : **C. Adams**

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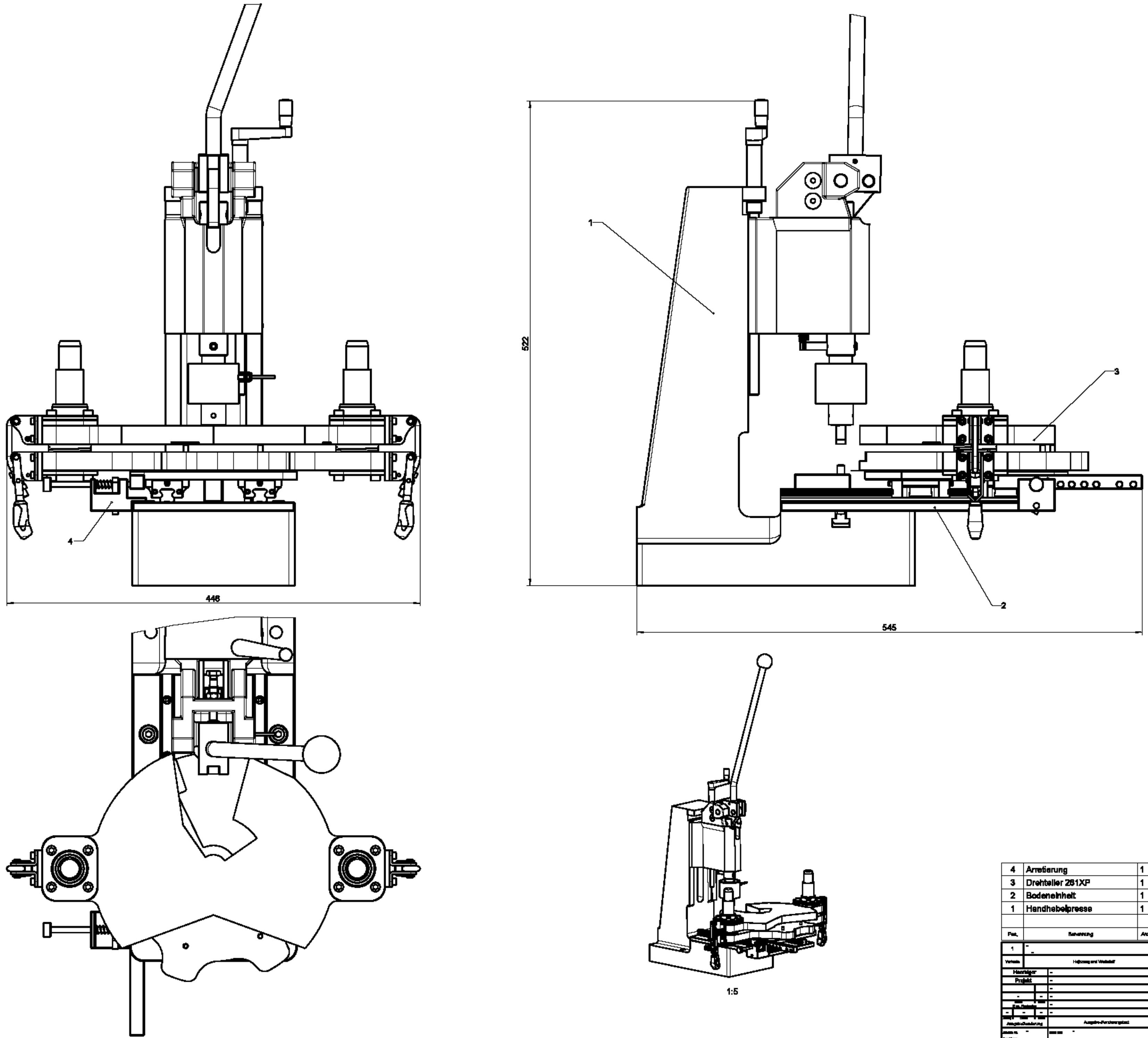
B. Assembly Drawings



Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung
4	Arretierung	1	Zusbau_Arretierung.asm		1,3
3	Drehteller 261XP	1	Zusbau_Drehteller.asm		1.2
2	Bodeneinheit	1	Zusbau_Boden.asm		1,1
1	Handhebelpresse	1	5501-6015-KE0000		

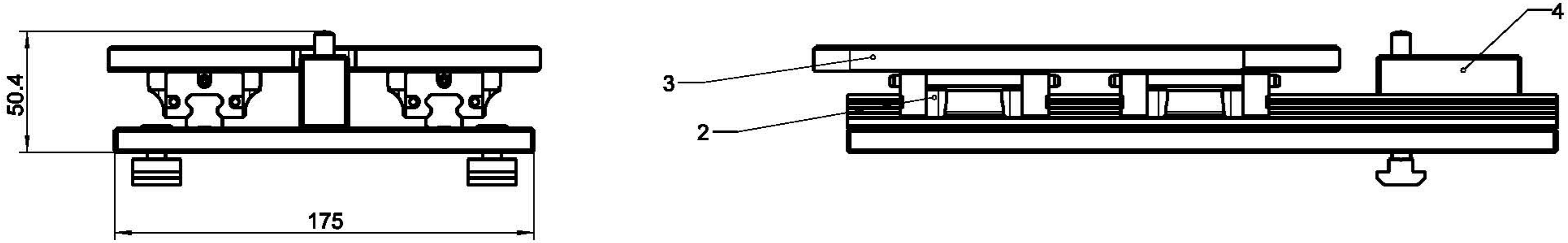
Toleranz ISO 8015
EN ISO 2768-mH
EN ISO 2768-mH

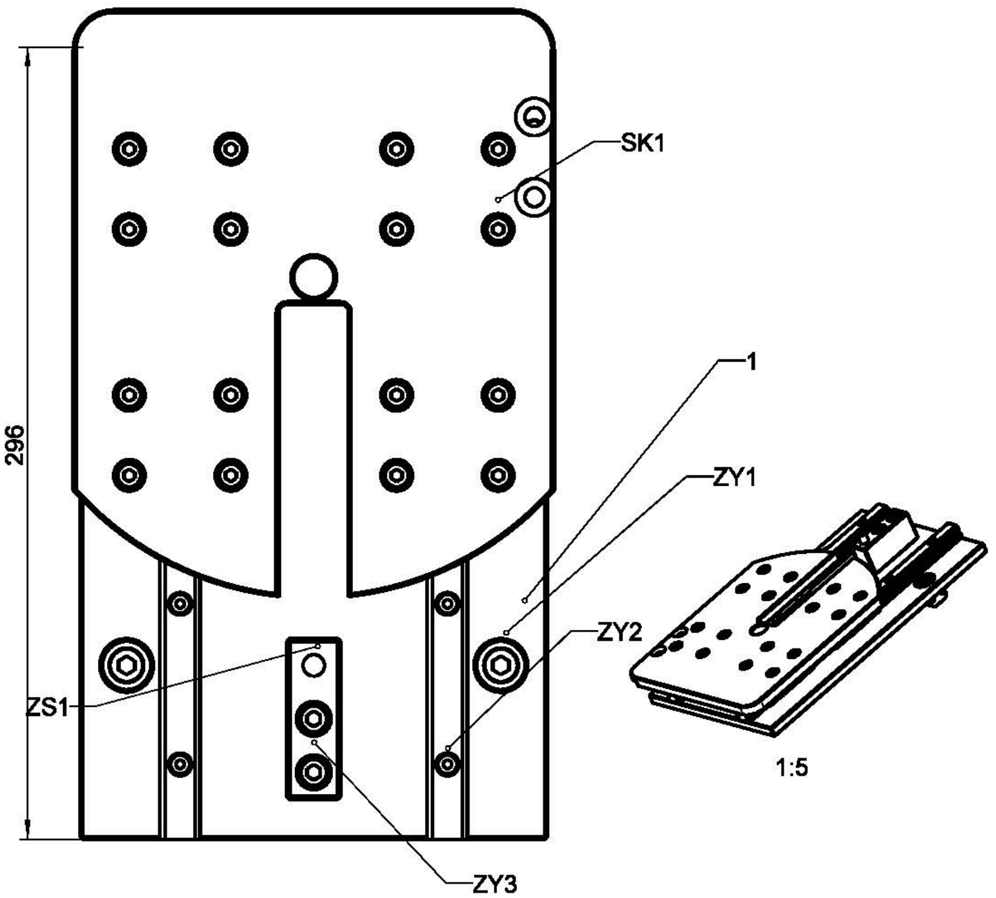
Maßstab 1:2

Bindenahtprüfstand
mit 261XP Drehteller

ZUSBAU_PRESSE

Blatt-Nr. 1 von 1 Index 1.0



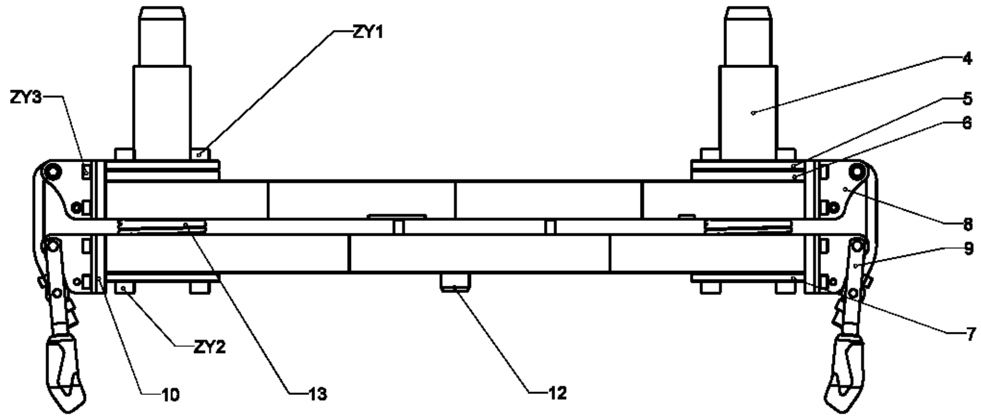


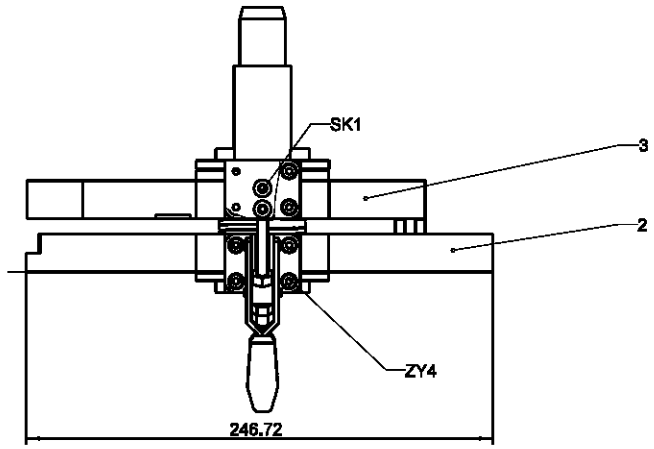
ZS1	Zylinderstift	1	DIN 7-h8-8x20	ungehärtet	
ZY4	Zylinderschraube	16	DIN 912-M5x10	8.8	
ZY3	Zylinderschraube	2	DIN 912-M6x30	8.8	
ZY2	Zylinderschraube	10	DIN 912-M4x16	8.8	
ZY1	Zylinderschraube	2	DIN 912-M8x16	8.8	
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung

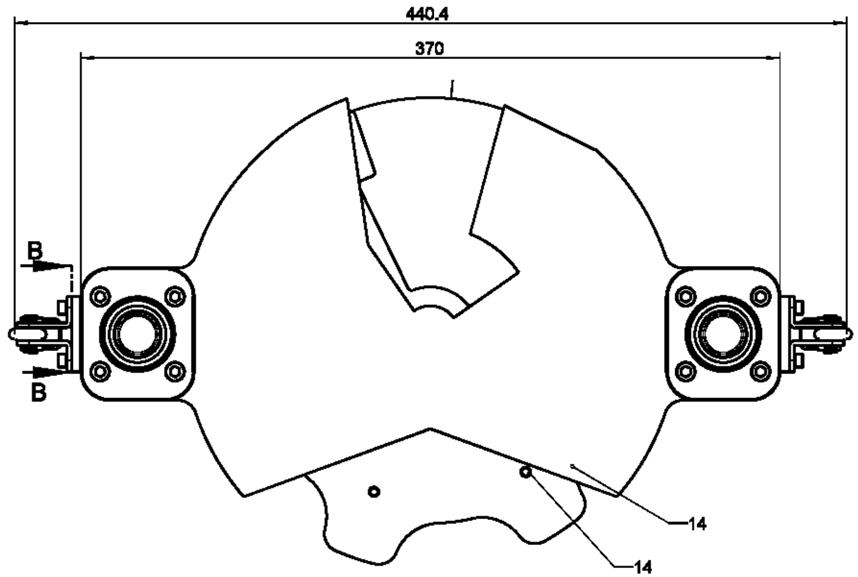
4	Stiftblock	1	Stiftblock.dwg	St	1.1.3
3	Träger unten	1	Trager_unten.dwg	St	1.1.2
2	Linearführung	2	LLTHS15A2T0296P5		SKF
1	Grundplatte	1	Grundplatte.dwg	St	1.1.1
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung

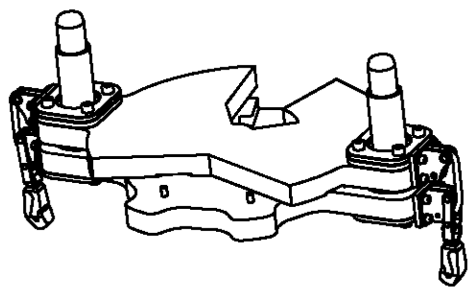
2	- -	-	- -	ZUSBAU_BODEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

-	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- - Datum Name	-	Maßstab	Zusammenbau Bodeneinheit		
Orig. Freigabe	-	1:2			
- - - Anzahl Datum Name	-				
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ZUSBAU_BODEN		
Ausgabe-Nr.: - Auslösung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 1	Index 1.1	







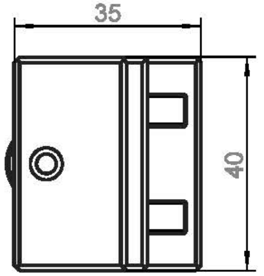


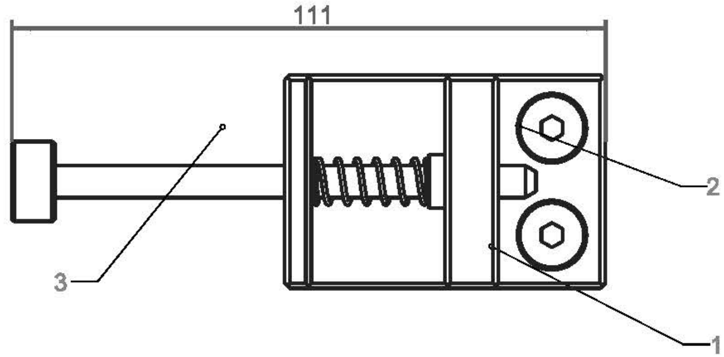
SK1	Senkkopfschraube	8	DIN 7991-M4x8	8.8	
ZY4	Zylinderschraube	2	DIN 912-M4x8	8.8	
ZY3	Zylinderschraube	16	DIN 912-M4x6	8.8	mit Scheibe
ZY2	Zylinderschraube	8	DIN 912-M6x10	8.8	
ZY1	Zylinderschraube	8	DIN 912-M6x16	8.8	
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung

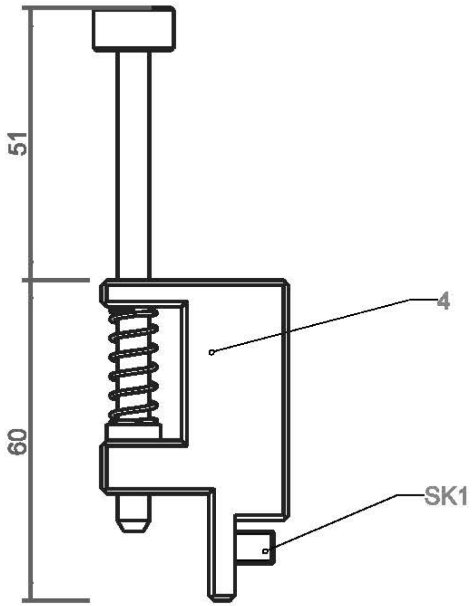
14	Zentrierstift	2	Zentrierstift.dwg		1.2.10
13	Druckfeder	2	D-263VH		Gutekunst Federn
12	Centerpin	1	Centerpin.dwg	St	1.2.9
11	-	-	-	-	-
10	Zwischenplatte	4	Zwischenplatte.dwg	St	1.2.7
9	Schnellspanner	2	AMF 94524		AMF
8	Schnellspannhaken	2	AMF 6847G		AMF
7	Abdeckung unten	2	Abdeckung_unten.dwg		1.2.6
6	Distanzplatte	2	Distanzplatte.dwg	Al	1.2.5
5	Abdeckung oben	2	Abdeckung_oben.dwg	Al	1.2.4
4	Führungssäule	2	E1325/24x140 45		Meusburger
3	Druckplatte	1	Druckplatte.dwg		1.2.3
2	Träger oben	1	Traeger_oben.dwg		1.2.2
1	-	-	-		-
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung

1	-	-	-	ZUSBAU_DREHTELLER
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflächenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.		Tolerierung ISO 8015
Projekt	-	Geprueft		EN ISO 2768-mH
	-	Norm		EN ISO 2768-mH
- -	-	Maßstab 1:2	Zusammenbau Drehteller 261 XP	
Orig. Freigabe	-			
- - -	-			
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN	ZUSBAU_DREHTELLER	
Ausgabe Nr. -	Ersatz fuer: -		Blatt-Nr. 1 von 1	Index 1.2 A
Ausfuehrung -	-			





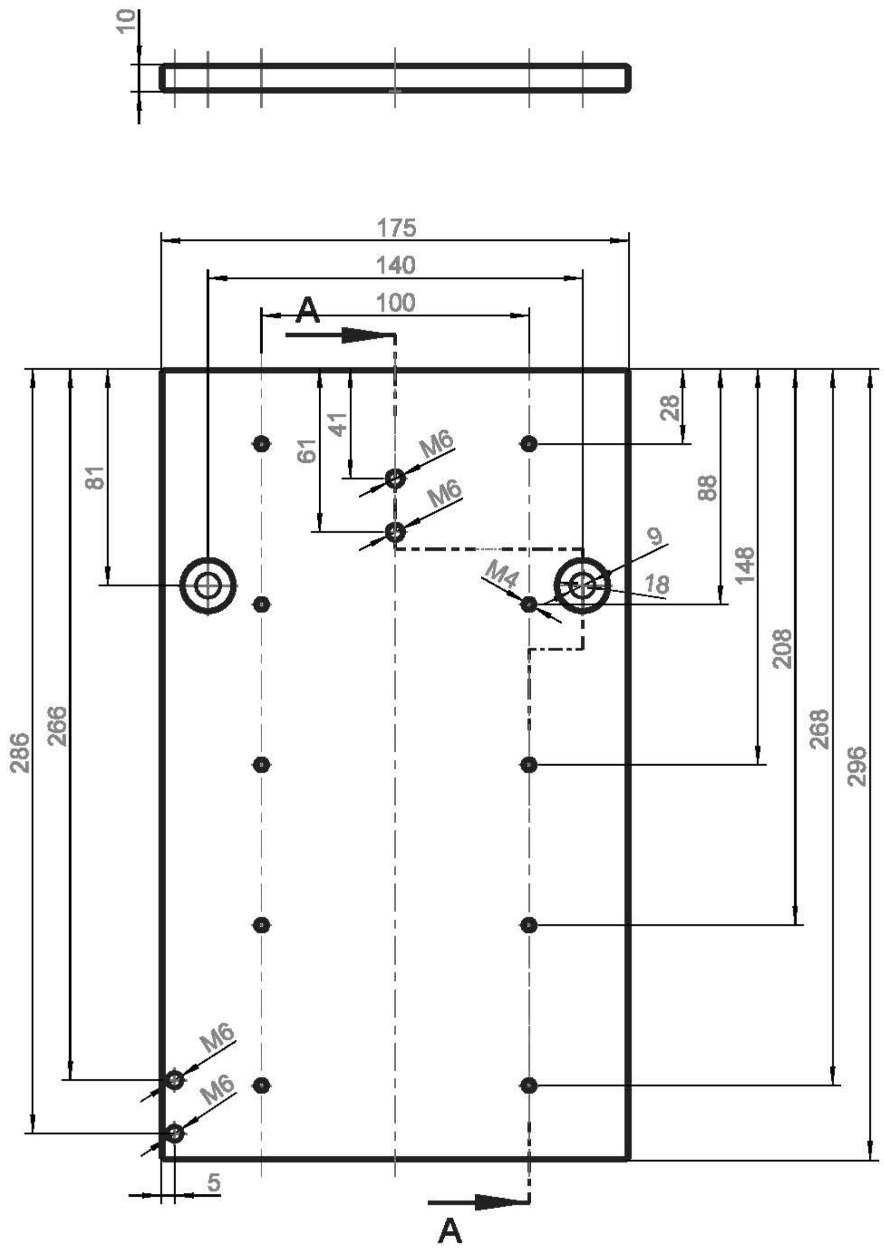


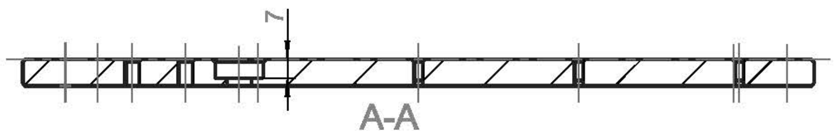
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung
ZK1	Zylinderkopfschraube	2	DIN 7991-M6x12	8.8	
Pos.	Benennung	Anzahl	Referenz	Werkstoff	Bemerkung
5					
4	Druckfeder	1	VD-197A		Gutekunst Federn
3	Arretierstange	1	Arretierstange.dwg	St	1.3.3
2	Arretierstangenspitze	1	Arretierstangenspitze.dwg	St	1.3.2
1	Arretierblock	1	Arretierblock.dwg	St	1.3.1

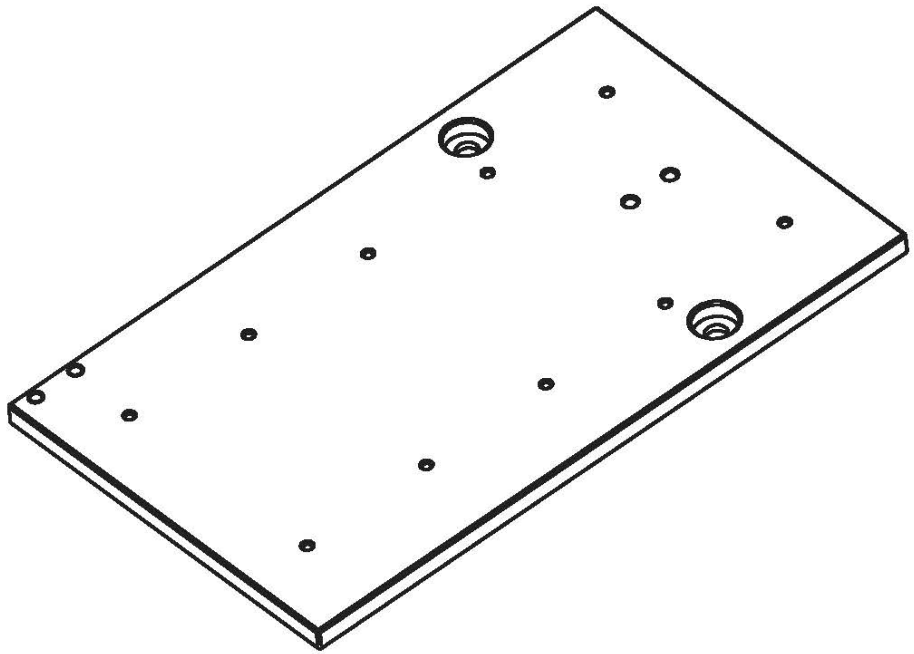
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.
1	- -	-	- -	ZUSBAU_ARRETIERUNG

Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- (Datum) - (Name) Orig. Freigabe	-	Maßstab 1:1	Zusammenbau Arretierung		
- - - (Anzahl, Datum, Name) Ausgabe/Aenderung	-				
	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ZUSBAU_ARRETIERUNG		
Ausgabe Nr. -	Ersatz fuer: -		Blatt-Nr. 1 von 1	Index 1.3	
Auswertung: -	-				

C. Single Part Drawings

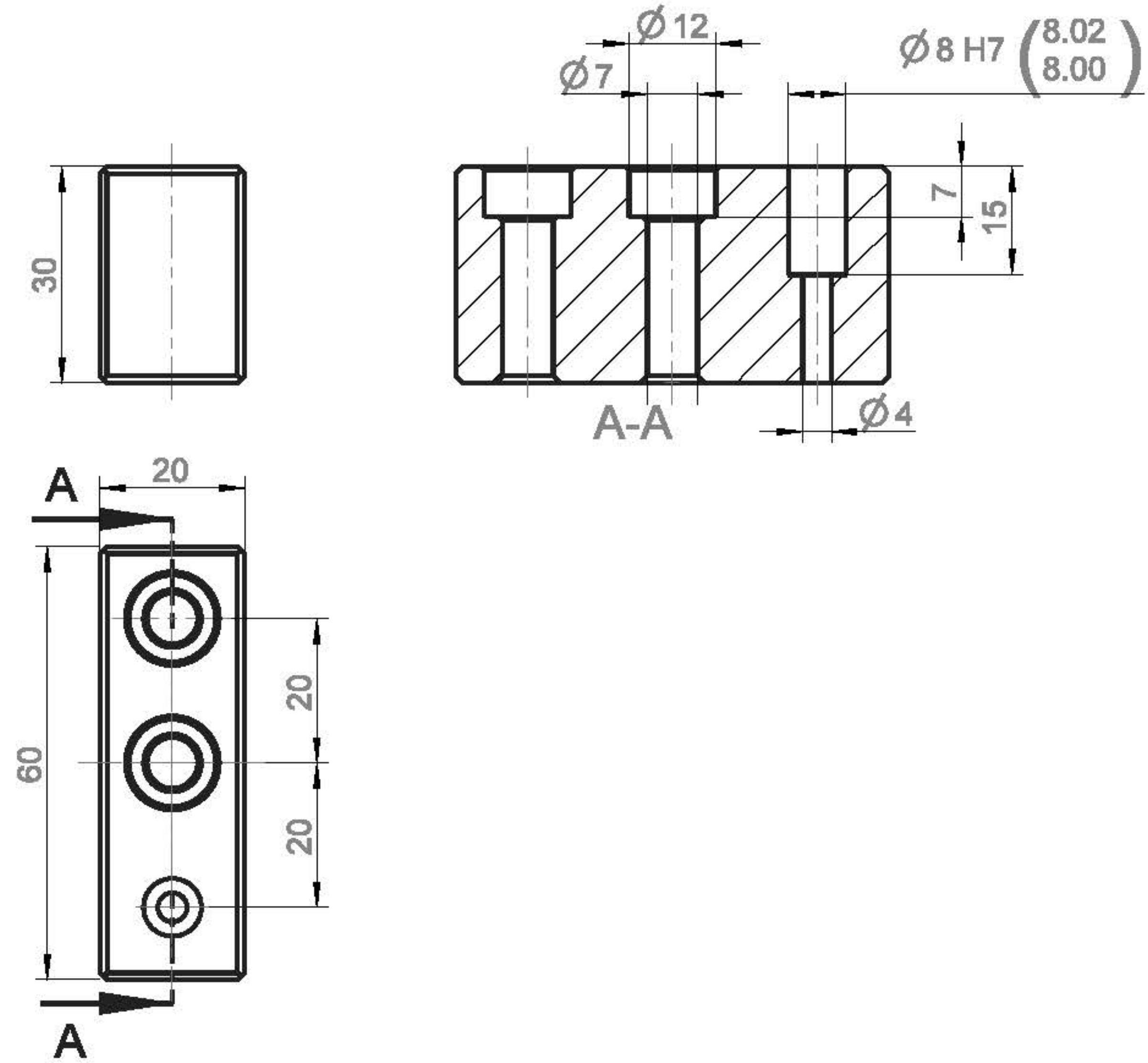






Alle nicht bemaßten Fasen mit 0,5x45°

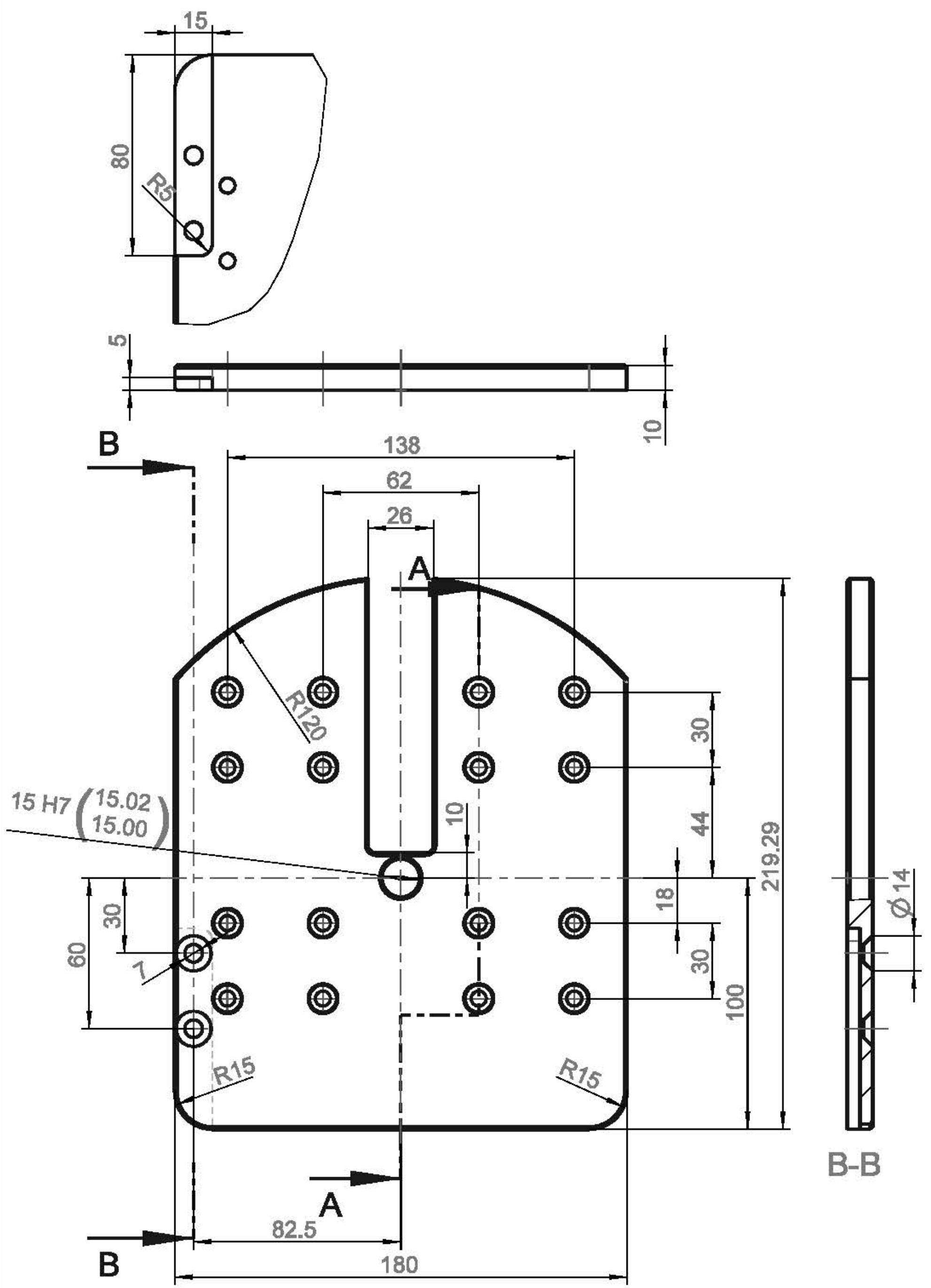
1	St -		-	- -		GRUNPLATTE
Variante	Halbzeug und Werkstoff		Rohteil-Nummer	Oberflaechenbehandlung		Teil-, Baugruppen-Nr.
Hoerbiger	-		Bearb.		Tolerierung ISO 8015	
Projekt	-		Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-		Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- / - (Datum / Name) Orig. Freigabe	-		Maßstab 1:2	Grundplatte		
- / - / - (Anzahl / Datum / Name) Ausgabe/Aenderung	-					
	-					
	Ausgabe-/Aenderungstext		KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	GRUNDPLATTE		
Ausgabe Nr. -	Ersatz fuer: -			Blatt-Nr. 1 von 1		Index 1.1.1
Auswertung: -	-					

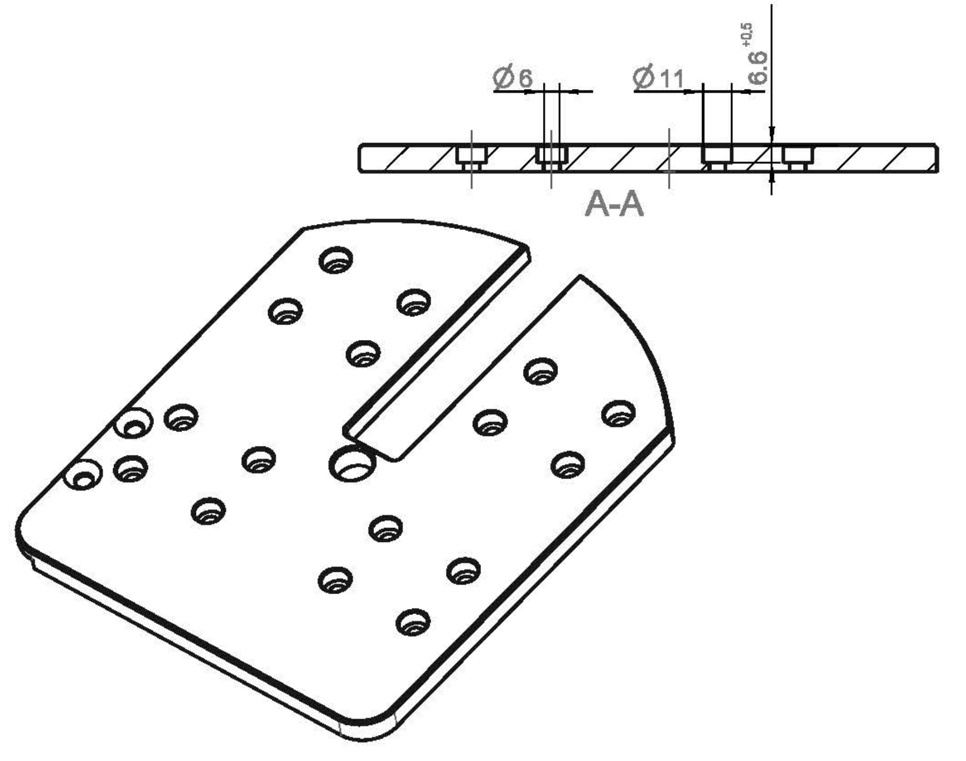


Alle nicht bemaßten Fasen mit 0,5x45°

1	St -	-	- -	STIFTBLOCK
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft			Laengen-toleranzen: EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen: EN ISO 2768-mH
- - (Datum, Name) Org. Freigabe	-	Maßstab 1:1	Stiftblock für Kulissensteuerung		
- - - (Anzahl, Datum, Name)	-				
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	STIFTBLOCK		
Ausgabe Nr. -	Ersatz fuer: -		Blatt-Nr. 1 von 1	Index 1.1.3	
Auswertung: -	-				

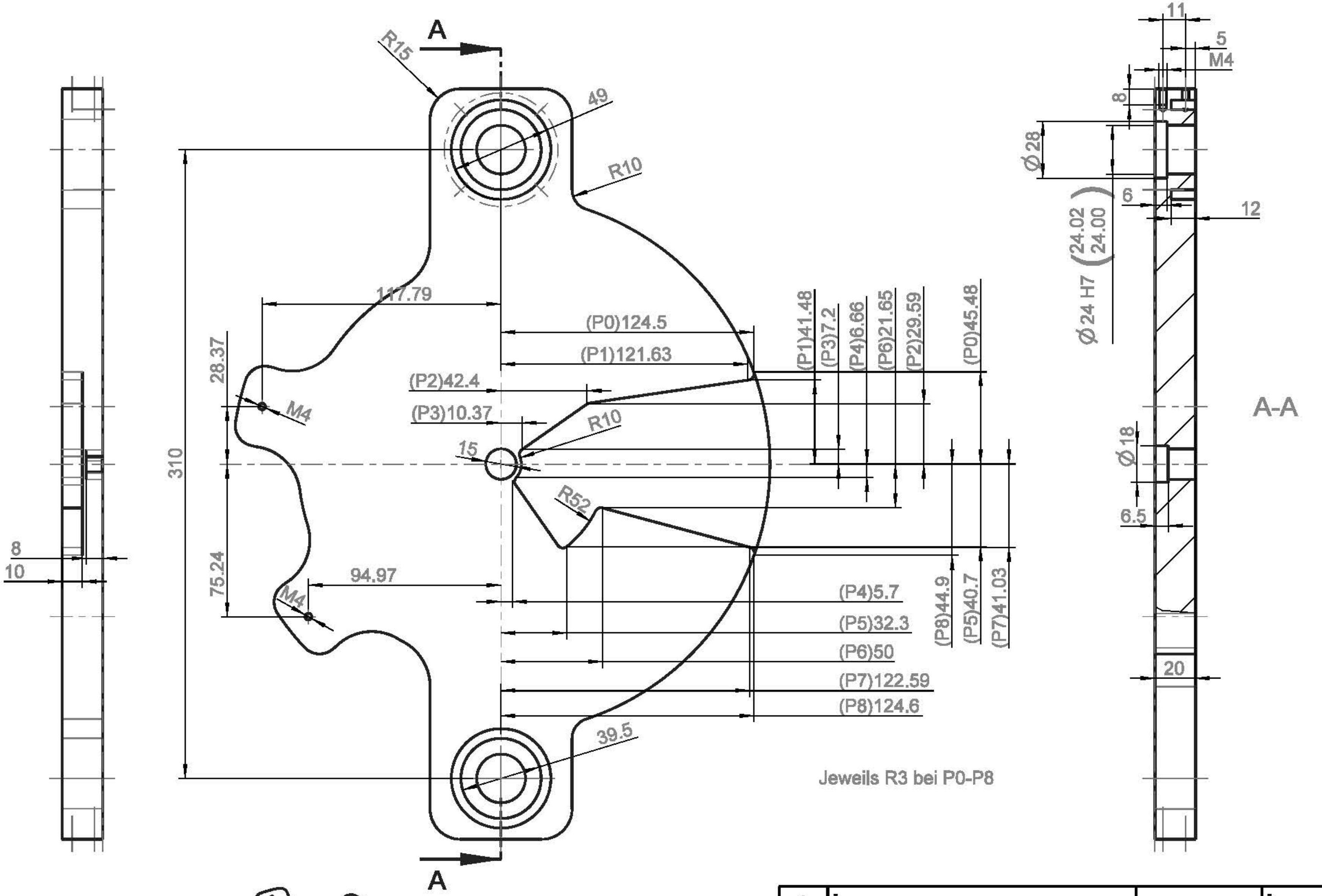


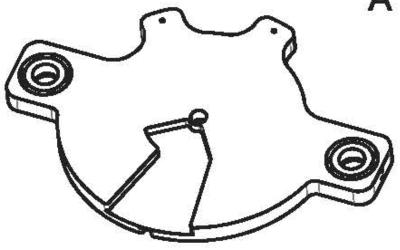


Alle nicht bemaßten Fasen mit 0,5x45°

2	St -	-	- -	TRAGER_UNTEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.		Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen: EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen: EN ISO 2768-mH
- - Datum Name Orig. Freigabe	-	Maßstab 1:2	Träger unten	
- - - Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	TRAGER_UNTEN	
Ausgabe Nr. - Ausfertigung -	Ersatz fuer: - -		Blatt-Nr. 1 von 1 Index 1.1.2	

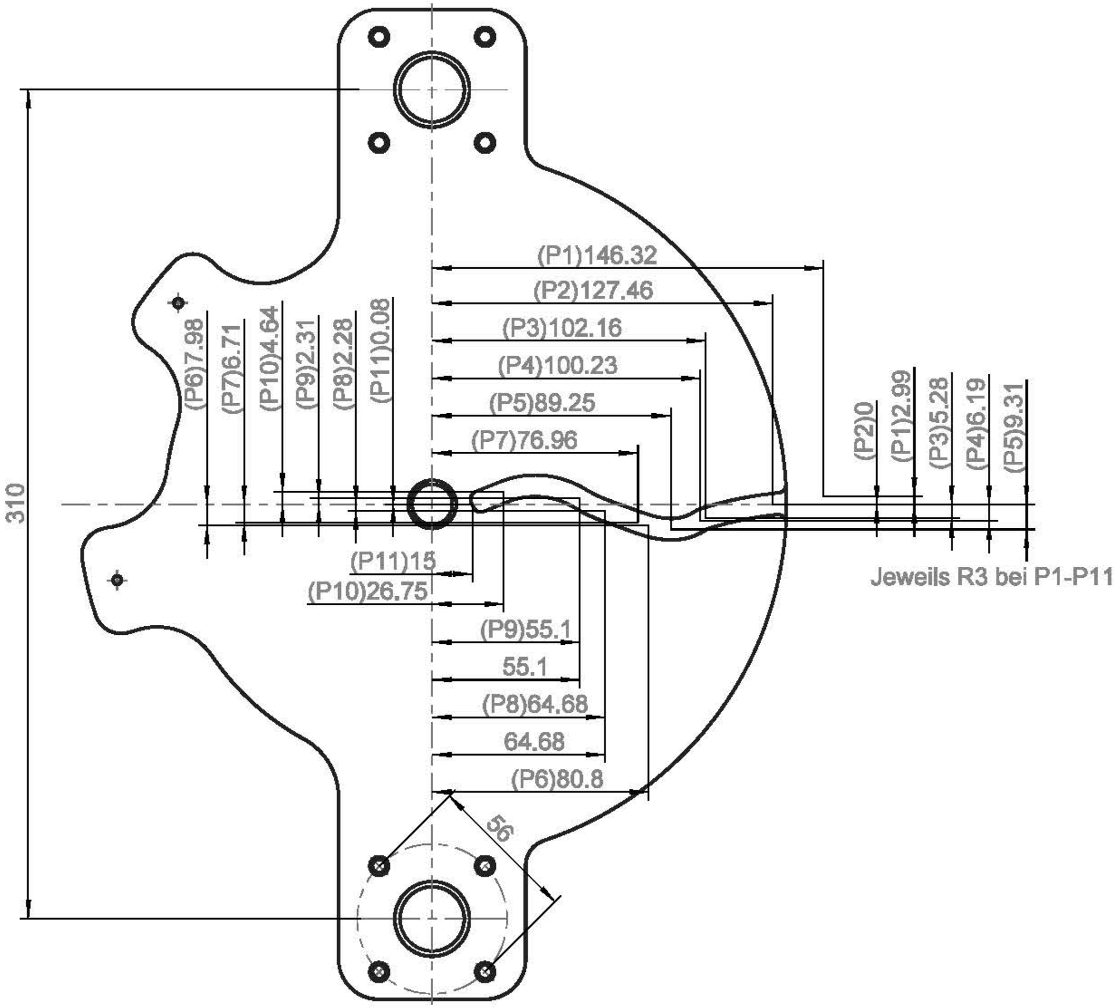


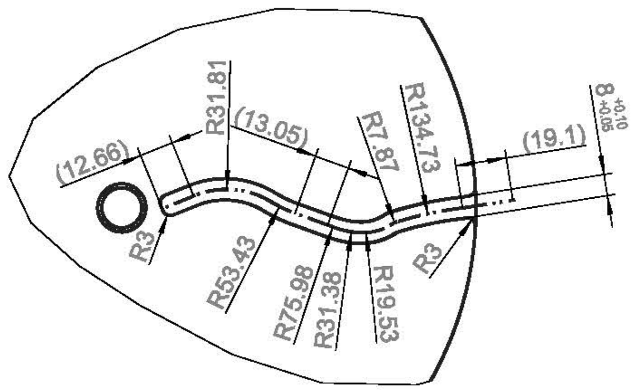


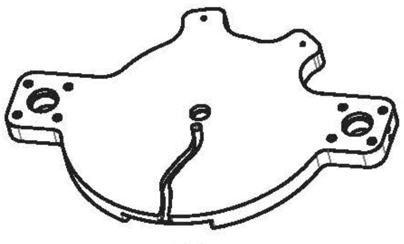
1:5

2	- -	-	- -	TRAGER_OBEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.			Tolerierung ISO 8015	
Projekt	-	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- -	-	Maßstab 1:2	Träger oben Oberseite + Schnitt			
Datum Name Orig. Freigabe	-					
- - -	-					
Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	TRAEGER_OBEN			
Ausgabe Nr. - Auswirkung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 3	Index 1.2.2		

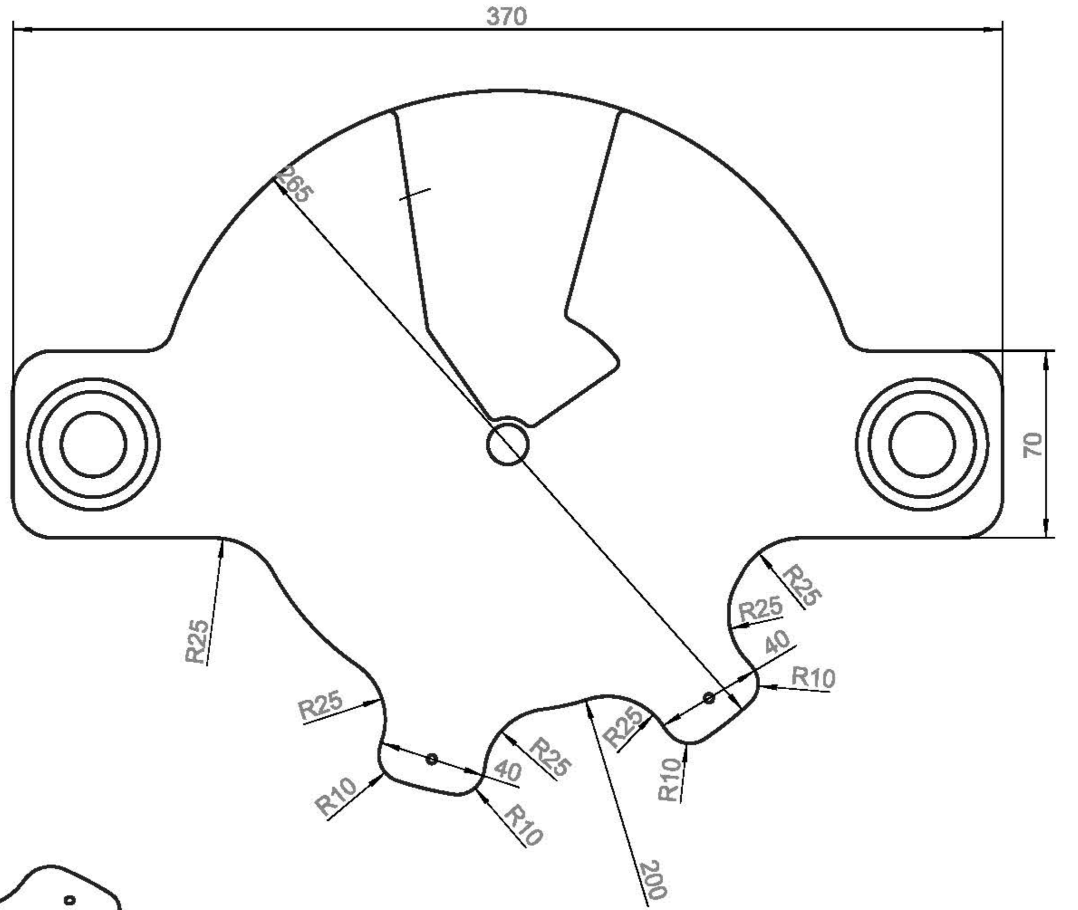


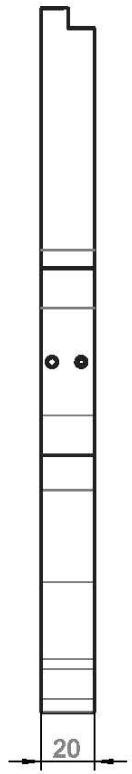


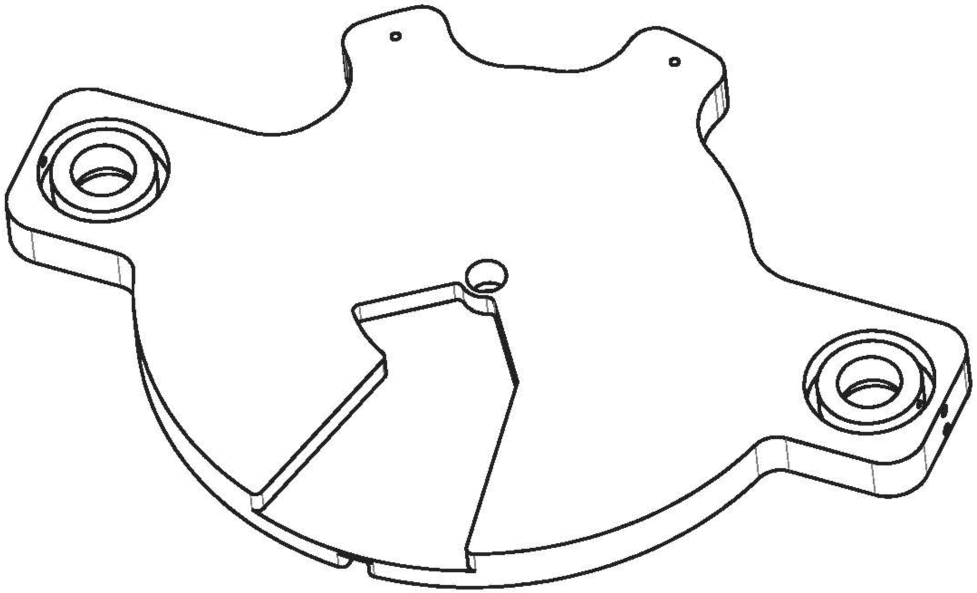


1:5

-	- -		-	- -	TRAGER_OBEN
Variante	Halbzeug und Werkstoff		Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.
-	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- - (Datum, Name) Orig. Freigabe	-	Maßstab 1:2	Träger oben Unterseite		
- - - (Anzahl, Datum, Name)	-				
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	TRAEGER_OBEN		
Ausgabe Nr. - Auslieferung: -	Ersatz fuer: - -		Blatt-Nr. 2 von 3		Index 1.2.2

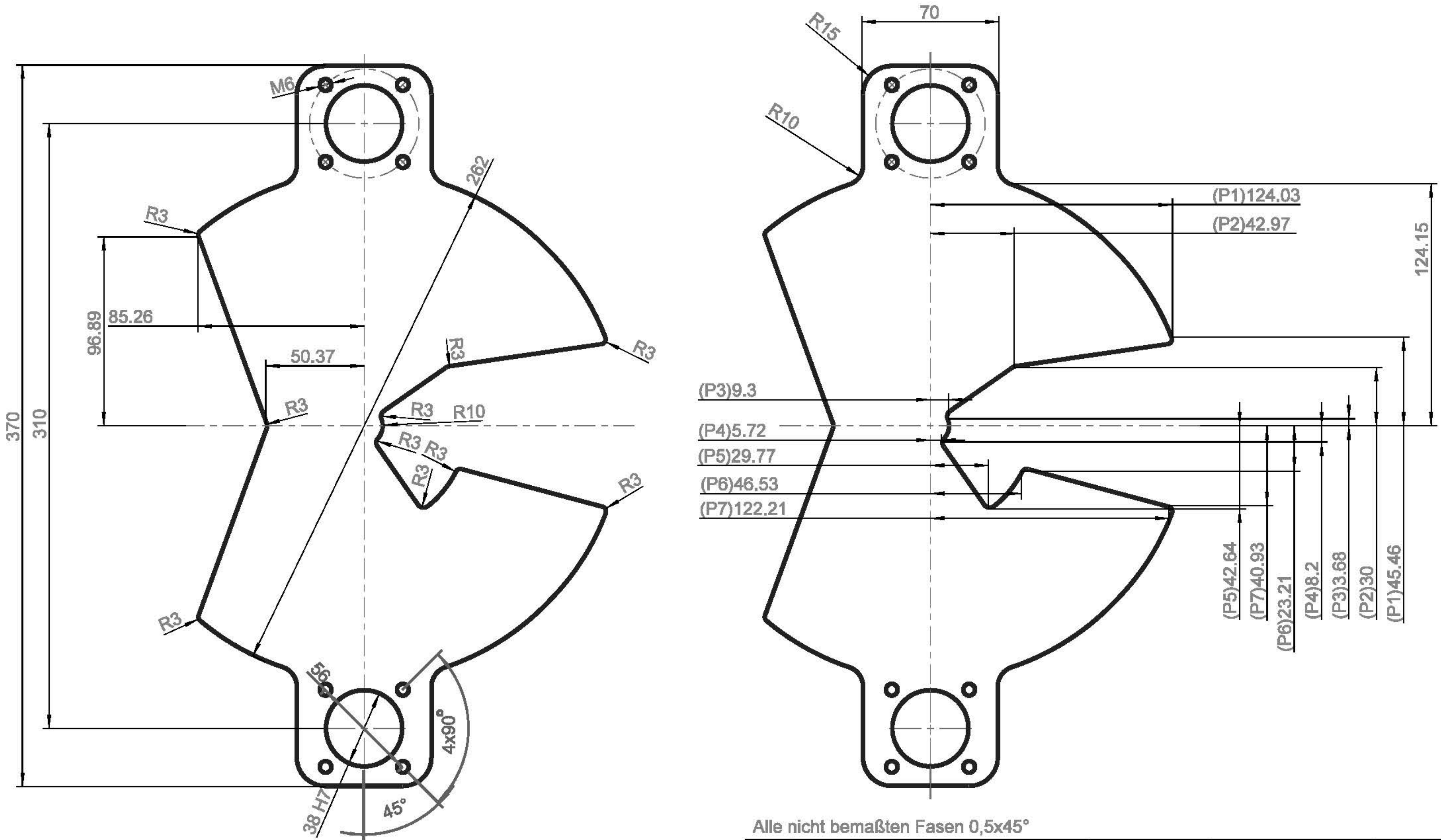






-	Aluminium -	-	- -	TRAGER_OBEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

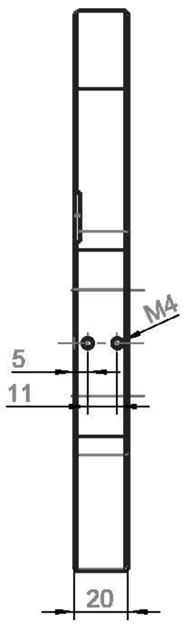
-	-	Bearb.			Tolerierung ISO 8015	
Projekt	-	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- - (Datum / Name) Orig. Freigabe	-	Maßstab 1:2	Traeger oben Grundabmaße			
- - - (Anzahl / Datum / Name)	- -					
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	TRAEGER_OBEN			
Ausgabe Nr. - Auslieferung: -	Ersatz fuer: - -		Blatt-Nr. 3 von 3	Index 1.2.2		

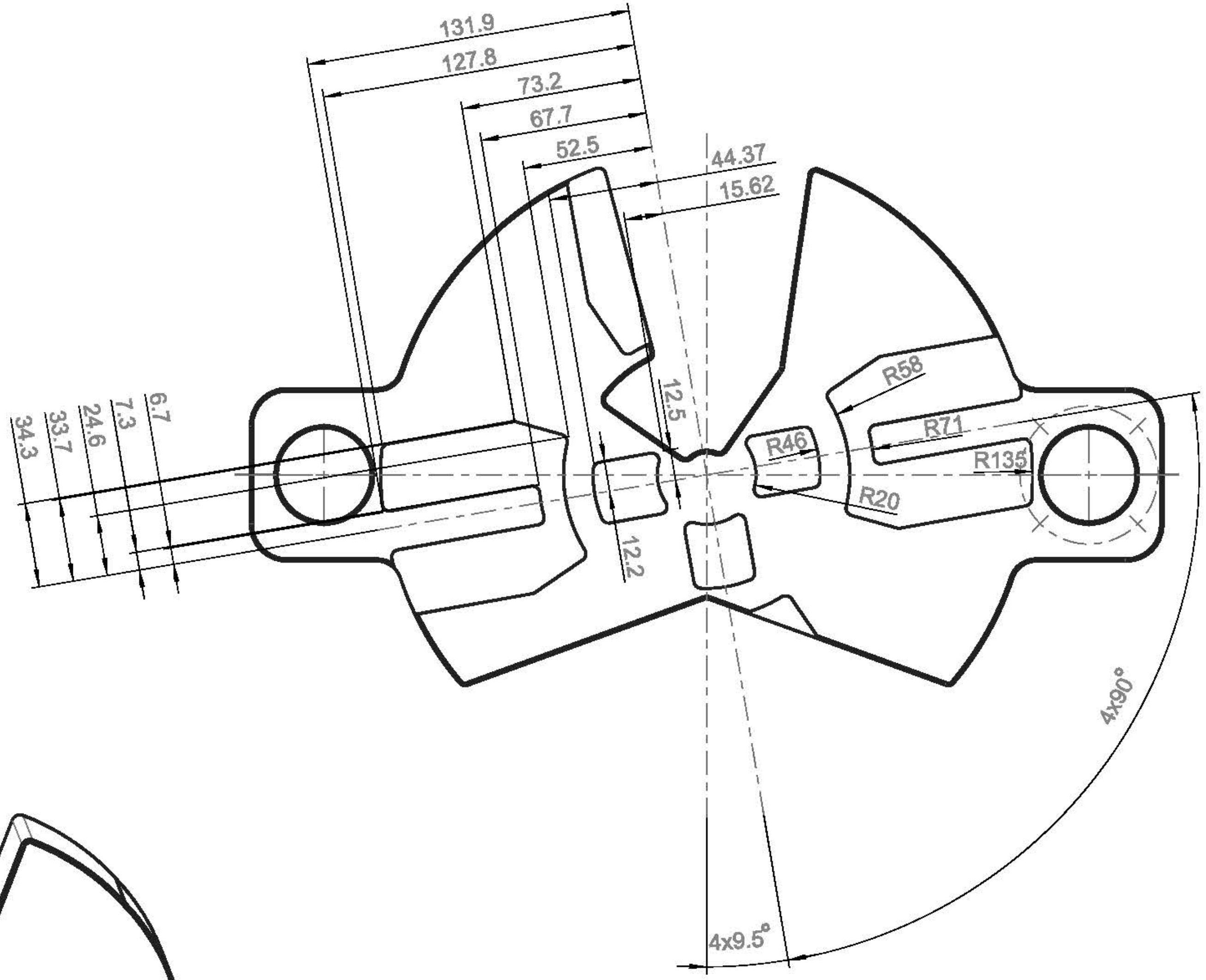


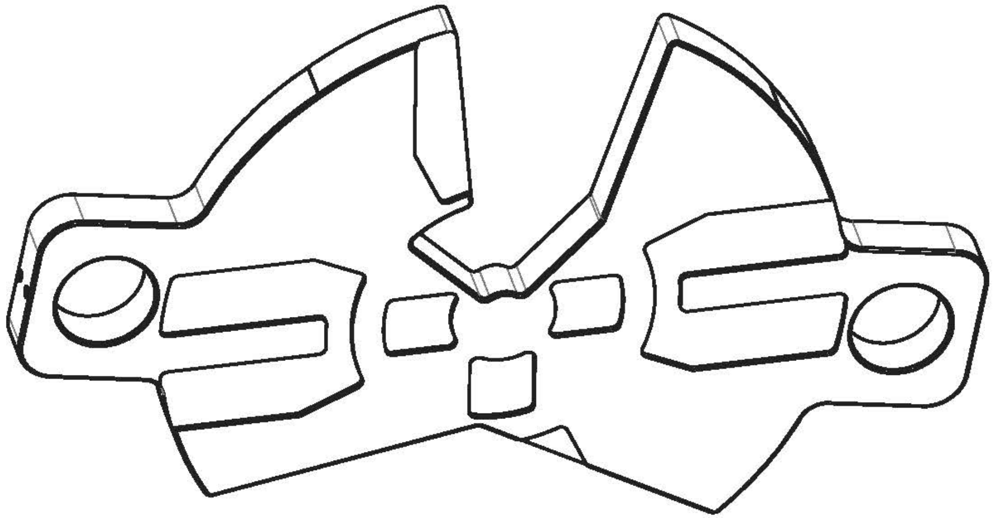
Alle nicht bemaßten Fasen 0,5x45°

-	- -		-	- -		DRUCKPLATTE
Variante	Halbzeug und Werkstoff		Rohteil-Nummer	Oberflaechenbehandlung		Teil-, Baugruppen-Nr.

-	-	Bearb.			Tolerierung ISO 8015	
Projekt	Bindenahtprüfstand	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
01.04.2016 MS	-	Maßstab	Bemaßung Oberseite			
Datum Name	-	1:2	Blatt_1			
Orig. Freigabe						
- - -	-					
Anzahl Datum Name						
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	DRUCKPLATTE			
Ausgabe Nr. -	Ersatz fuer: -		Blatt-Nr. 1 von 2		Index 1.2.3	
Auswertung: -	-					





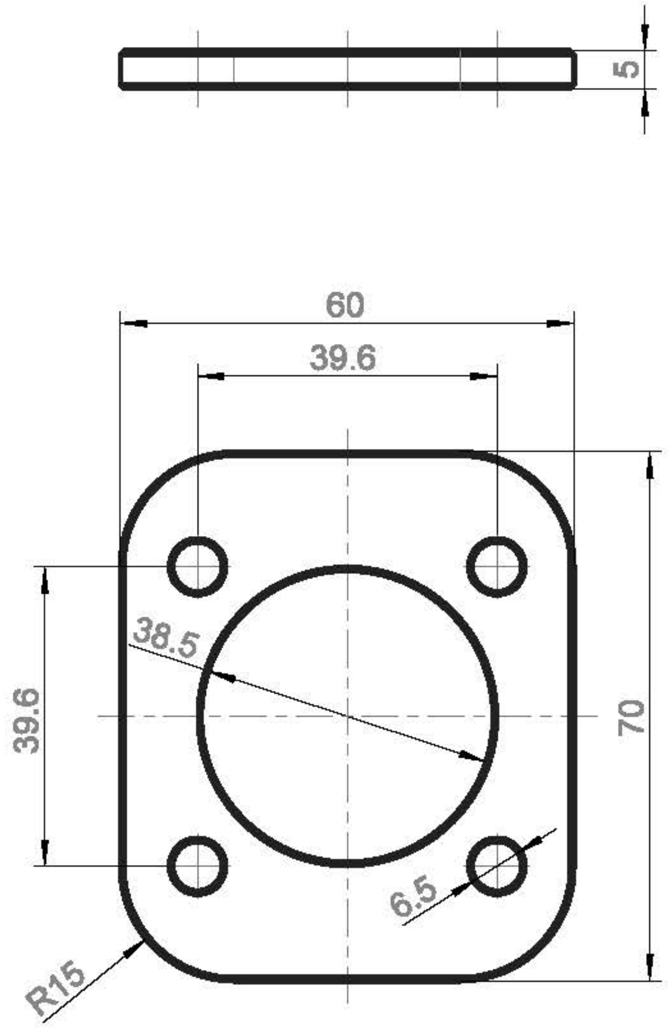


Alle nicht bemaßten Radien der Geometrie: R3

Alle nicht bemaßten Fasen 0,5x45°

-	-	-	-	DRUCKPLATTE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

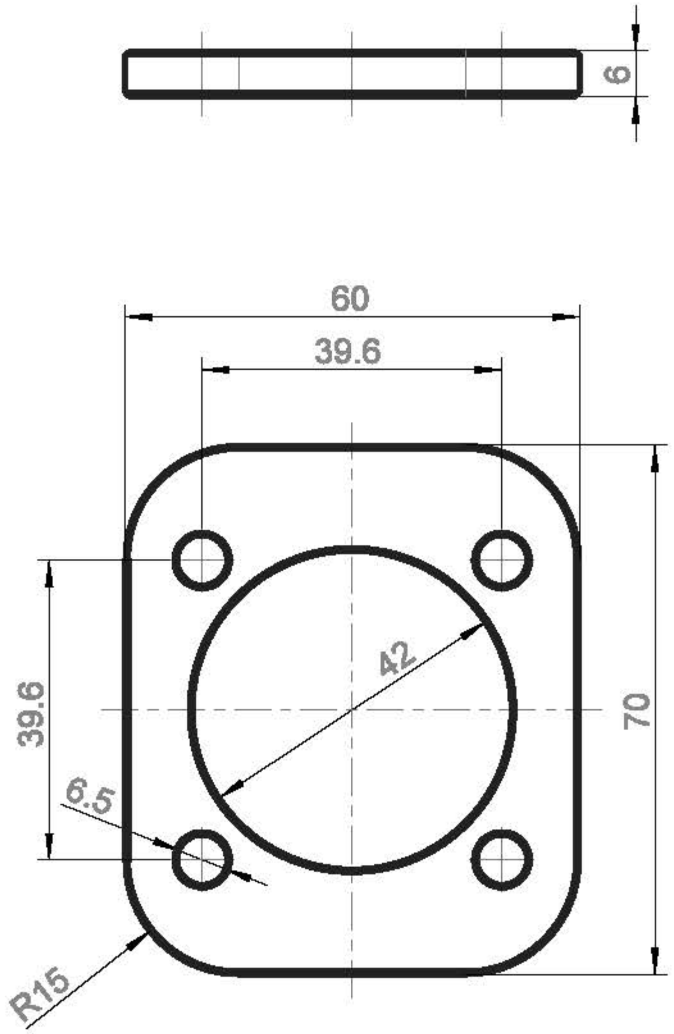
-	-	Bearb.		Tolerierung ISO 8015
Projekt	-	Geprueft	Laengen-toleranzen	EN ISO 2768-mH
	-	Norm	Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- - Datum Name Orig. Freigabe	-	Maßstab 1:2	Bemaßung Unterseite	Blatt 2
Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	DRUCKPLATTE	
Ausgabe Nr. - Ausstellung -	Ersatz für: -		Blatt-Nr. 2 von 2	Index 1.2.3



Alle nicht bemaßten Fasen 0,5x45°

1	- -	-	- -	ABDECKUNG_OBEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

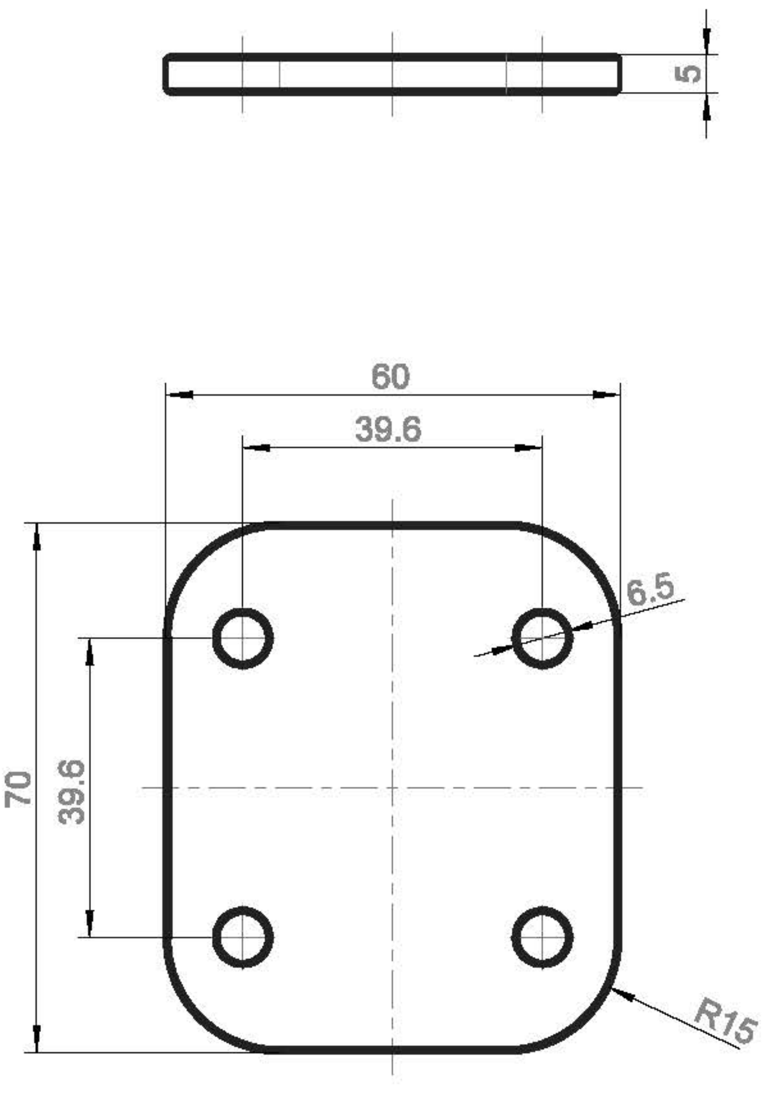
Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- - (Datum / Name)	-	Maßstab	Abdeckung oben		
Org. Freigabe	-	1:1			
- - - (Anzahl / Datum / Name)	-				
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ABDECKUNG_OBEN		
Ausgabe Nr. -	Ersatz fuer: -				
Auswirkung: -	-		Blatt-Nr. 1 von 1	Index 1.2.4	



Alle nicht bemaßten Fasen 0,5x45°

1	- -	-	- -	DISTANZPLATTE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

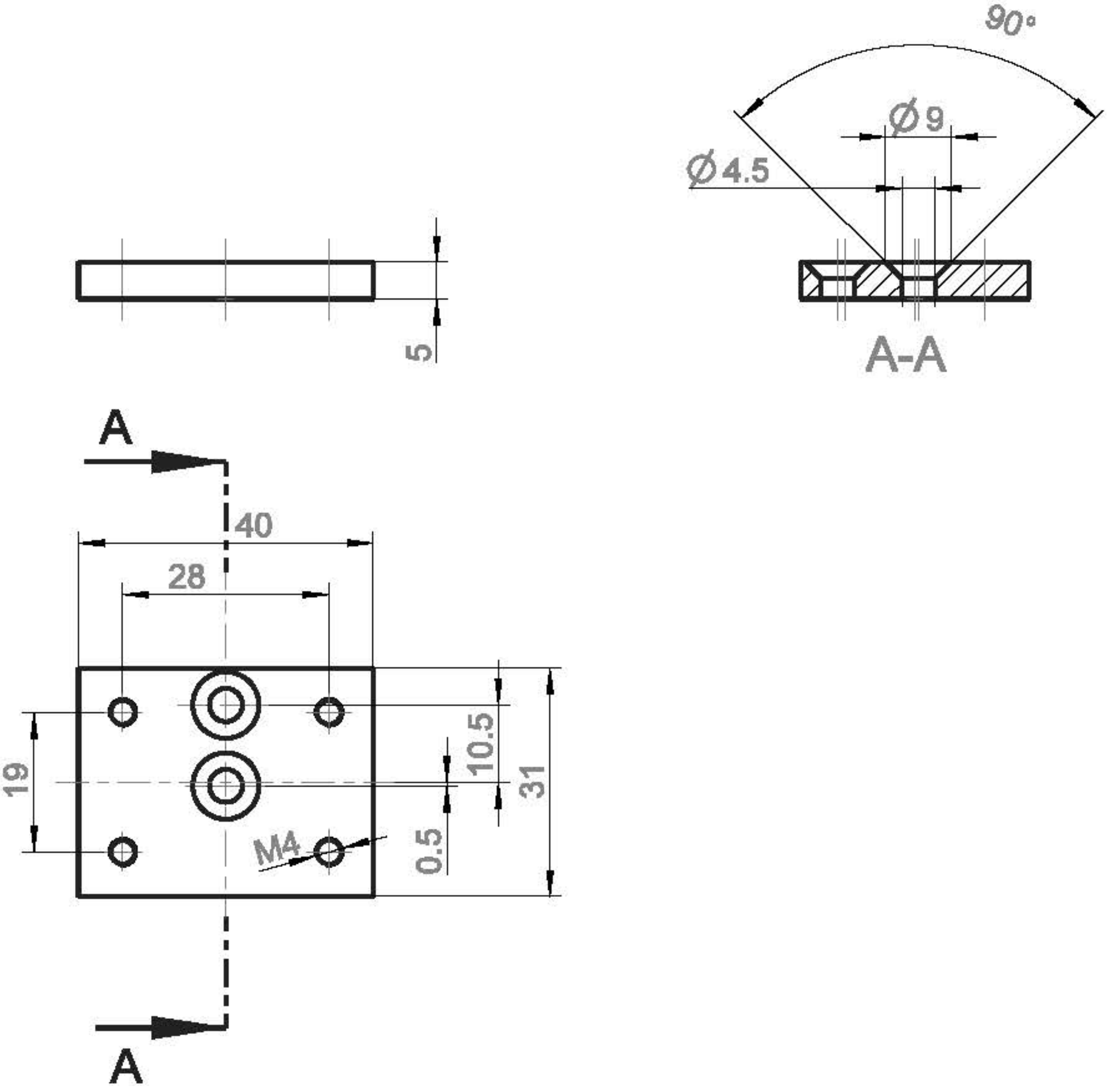
Hoerbiger		-	Bearb.			Tolerierung ISO 8015	
Projekt		-	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
		-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
-	-	-	Maßstab	Distanzplatte			
Datum	Name	-	1:1				
Org. Freigabe							
- -	-	-					
Anzahl Datum	Name						
Ausgabe/Aenderung		Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN	DISTANZPLATTE			
Ausgabe Nr. -		Ersatz fuer: -	KUNSTSTOFFVERARBEITUNG				
Auswertung: -		-		Blatt-Nr. 1 von 1		Index	1.2.5



Alle nicht bemaßten Fasen 0,5x45°

1	- -	-	- -	ABDECKUNG_UNTEN
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

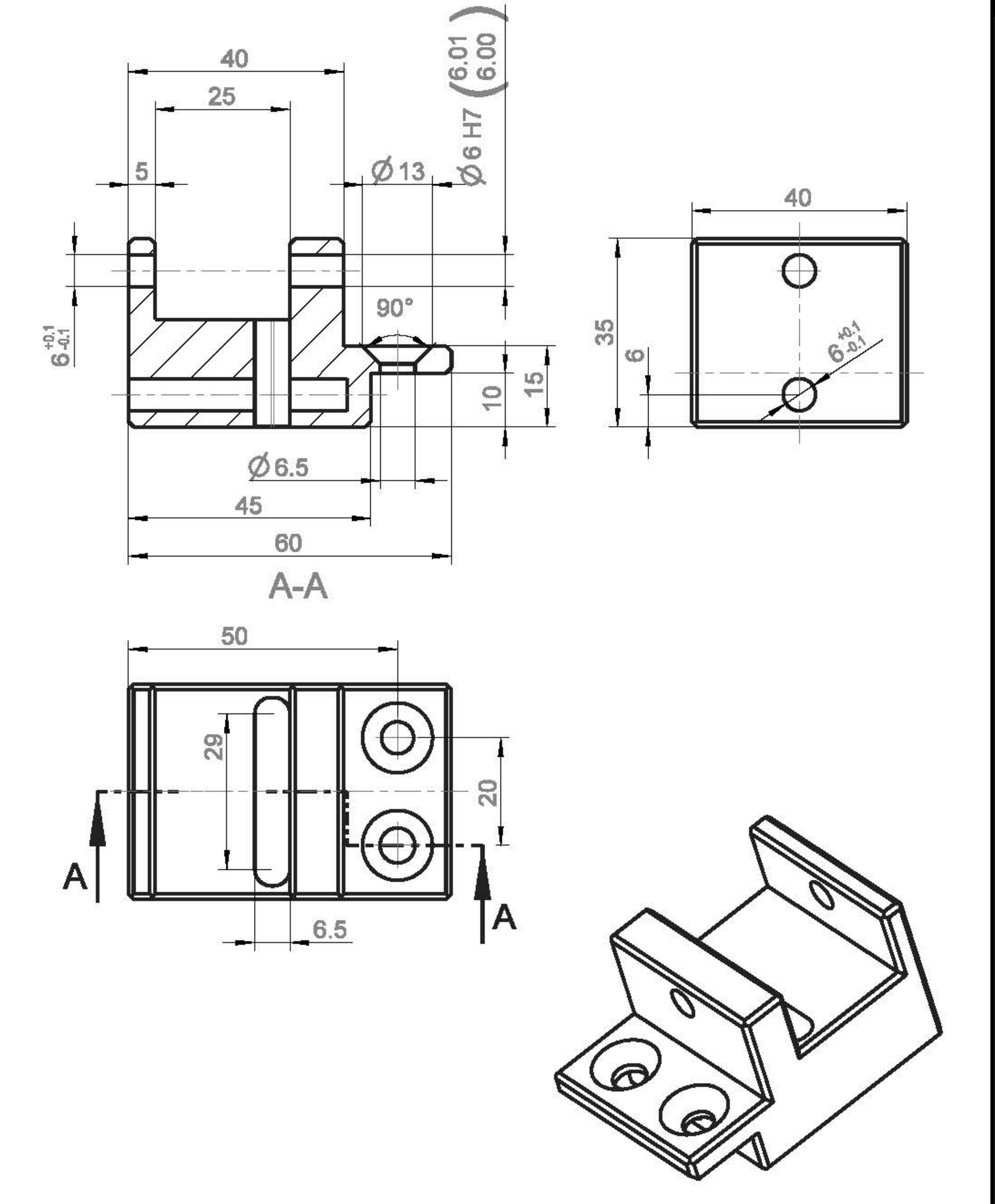
Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- -	-	Maßstab	Abdeckung unten		
Datum Name Org. Freigabe	-	1:1			
- - -	-				
Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ABDECKUNG_UNTEN		
Ausgabe Nr. - Auswirkung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 1	Index 1.2.6	



Alle nicht bemaßten Fasen 0,5x45°

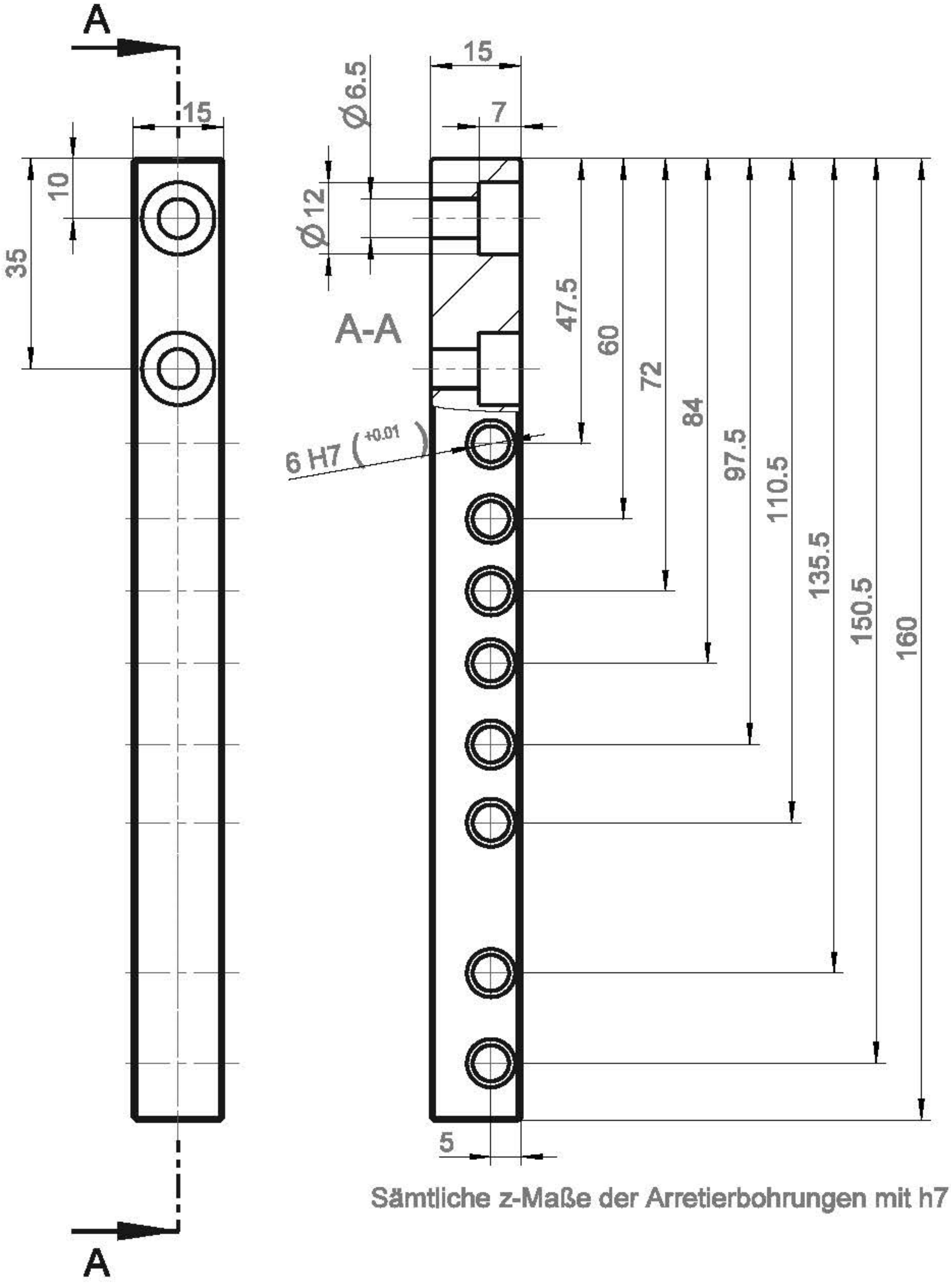
1	St -	-	- -	ZWISCHENPLATTE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.			Tolerierung ISO 8015	
Projekt	-	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- | - (Datum | Name)	-	Maßstab 1:1	Zwischenplatte			
Org. Freigabe	-					
- | - | - (Anzahl | Datum | Name)	-					
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ZWISCHENPLATTE			
Ausgabe Nr. - Auswertung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 1	Index 1.2.7		



Alle nicht bemaßten Fasen mit 0.5x45°

2	St -		-		- -	ARRETIERBLOCK
Variante	Halbzeug und Werkstoff		Rohteil-Nummer		Oberflaechenbehandlung	Teil-, Baugruppen-Nr.
Hoerbiger	-		Bearb.	05.09.16		Tolerierung ISO 8015
Projekt	-		Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-		Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- -	-		Maßstab	Arretierblock		
Datum / Name Org. Freigabe	-		1:1			
- - -	-					
Anzahl / Datum / Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext		KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG		ARRETIERBLOCK	
Ausgabe Nr. -	Ersatz fuer: -				Blatt-Nr. 1 von 1	Index 1.3.1
Auswirkung: -	-					

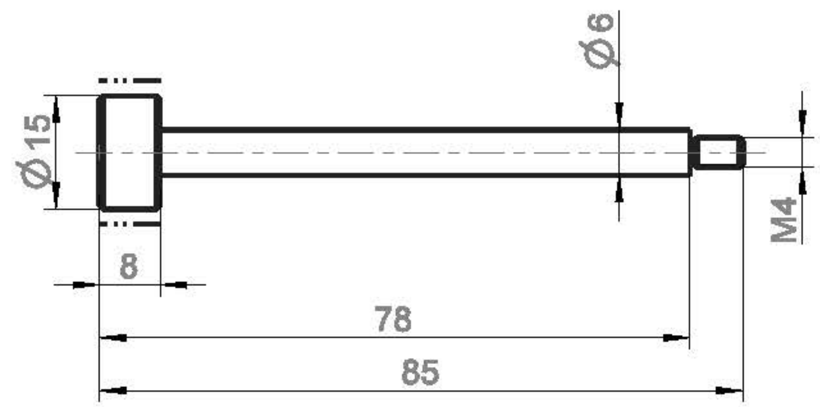


Sämtliche z-Maße der Arretierbohrungen mit h7

Alle nicht bemaßten Fasen 0,5x45°

1	St -	-	- -	ARRETIERLEISTE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

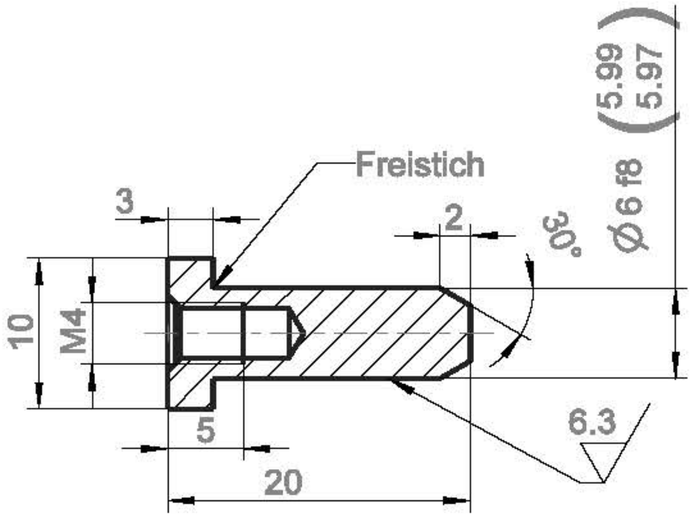
Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- / -	-	Maßstab			
Datum / Name Org. Freigabe	-	1:1	Arretierleiste		
- / - / -	-				
Anzahl / Datum / Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ARRETIERLEISTE		
Ausgabe Nr. -	Ersatz fuer: -				
Auswertung: -	-		Blatt-Nr. 1 von 1	Index 1.2.8	



Kreuzrändel

1	St -	-	- -	ARRETIERSTANGE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

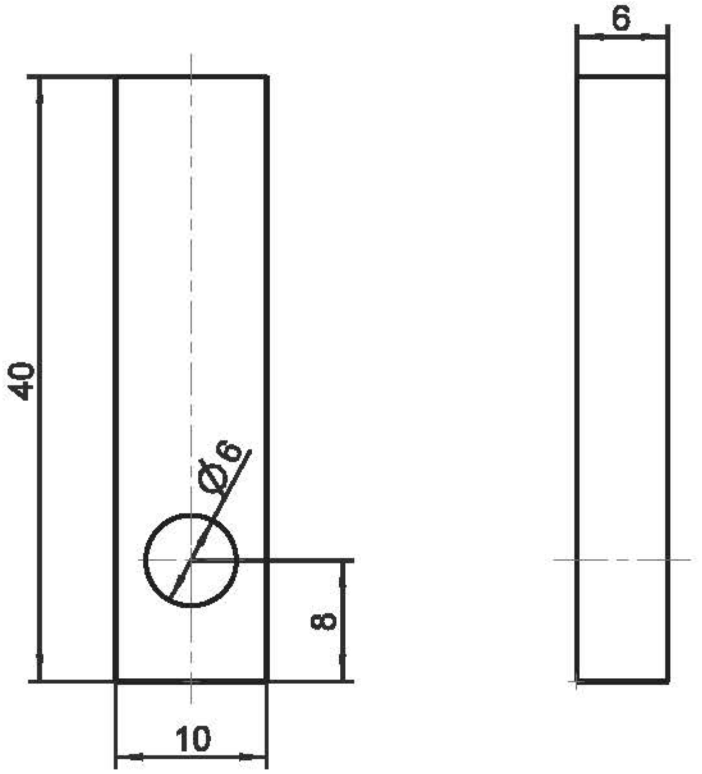
Hoerbiger	-	Bearb.			Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- (Datum) - (Name)	-	Maßstab	Arretierstange		
Org. Freigabe	-	1:1			
- (Anzahl) - (Datum) - (Name)	-				
Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ARRETIERSTANGE		
Ausgabe Nr. - Ausmärtung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 1	Index 1.3.3	



A-A

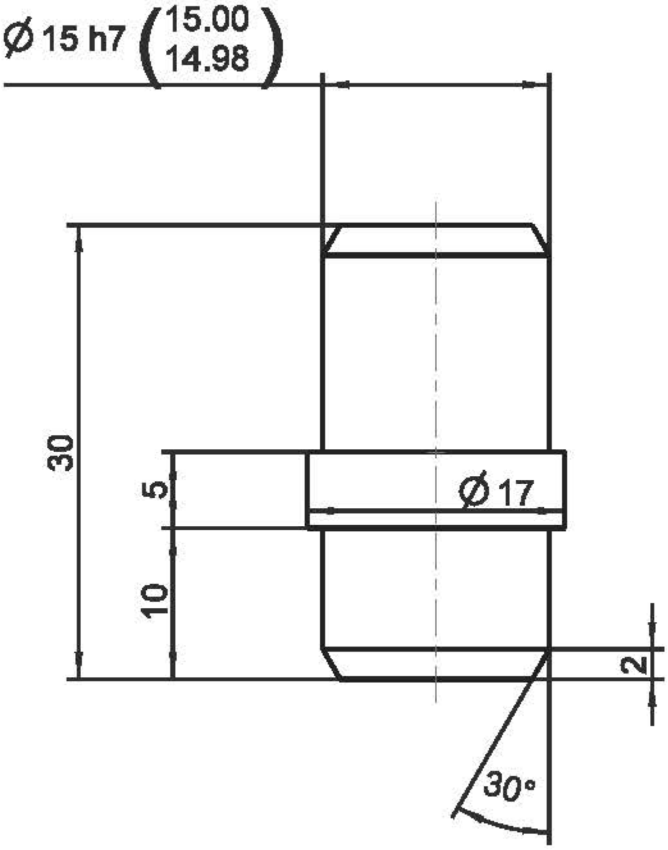
1	St -	-	- -	ARRETIERSTANGE_SPITZE
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

-	-	Bearb.		Tolerierung ISO 8015
Projekt	-	Geprueft		Laengen-toleranzen: EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen: EN ISO 2768-mH
- / -	-	Maßstab	Arretierstangenspitze	
Datum / Name Org. Freigabe	-	2:1		
- / - / -	-			
Anzahl / Datum / Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ARRETIERSTANGENSPITZE	
Ausgabe Nr. -	Ersatz fuer: -		Blatt-Nr. 1 von 1	Index 1.3.2
Auswertung: -	-			



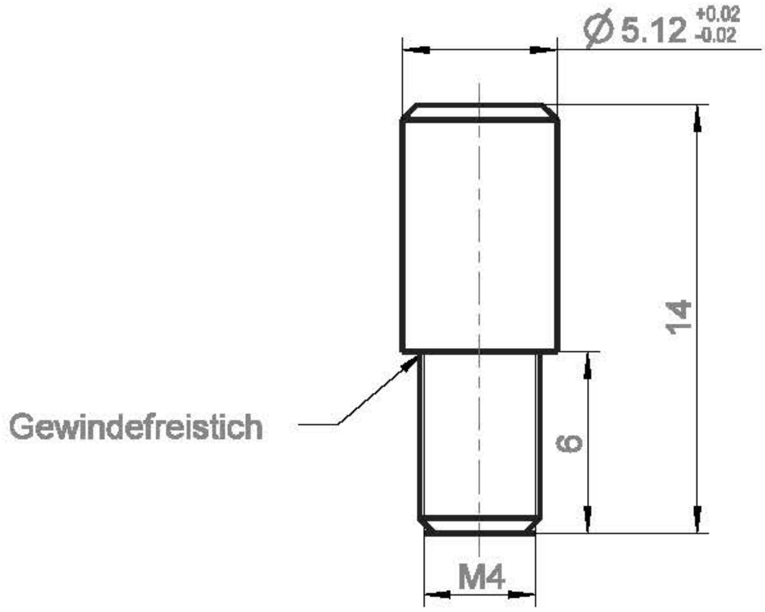
1	Aluminium/Stahl -	-	- -	ARRETIERUNGSRUECKHALTER
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

-	-	Bearb.			Tolerierung ISO 8015	
Projekt	-	GepruefT			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- | -	-	Maßstab	Arretierungssperre			
Datum | Name Org. Freigabe	-	2:1				
- | - | -	-					
Anzahl | Datum | Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ARRETIERUNGSRUECKHALTER			
Ausgabe Nr. - Auswertung: -	Ersatz fuer: - -		Blatt-Nr. 1 von 1		Index -	



1	St Ø 17x30 -	-	- -	CENTERPIN_203CP
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

-	-	Bearb.	Schmid M.		Tolerierung ISO 8015
Projekt	Hoerbiger	Geprueft		Laengen-toleranzen	EN ISO 2768-mH
	-	Norm		Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- -	-	Maßstab	Centerpin 203CP		
Datum Name Org. Freigabe	-	2:1			
- - -	-				
Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	CENTERPIN_203CP		
Ausgabe Nr. -	Ersatz fuer: -				
Auswertung: -	-		Blatt-Nr. 1 von 1	Index -	



Alle nicht bemaßten Fasen 0,5x45°

1	- -	-	- -	ZENTRIERSTIFT
Variante	Halbzeug und Werkstoff	Rohteil-Nummer	Oberflaechenbehandlung	Teil-, Baugruppen-Nr.

Hoerbiger	-	Bearb.			Tolerierung ISO 8015	
Projekt	-	Geprueft			Laengen-toleranzen	EN ISO 2768-mH
	-	Norm			Winkel-, Form-, Lage-Toleranzen	EN ISO 2768-mH
- -	-	Maßstab	Zentrierstift			
Datum Name Org. Freigabe	-	4:1				
- - -	-					
Anzahl Datum Name Ausgabe/Aenderung	Ausgabe-/Aenderungstext	KUNSTSTOFF TECHNIK LEOBEN KUNSTSTOFFVERARBEITUNG	ZENTRIERSTIFT			
Ausgabe Nr. -	Ersatz fuer: -					
Auswertung: -	-		Blatt-Nr. 1 von 1	Index 1.2.10		