

# MANUFACTURING PROCESS FOR EDGE PREPARATION OF SHEET METAL

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## Abstract:

In the Collaborative Research Centre 666 “Integral sheet metal design with higher order bifurcations”, the manufacturing processes of different disciplines are combined in a new way to generate multi-branched metal sheet structures of metal strips. A necessary precondition for the new recast metal forming of linear flow splitting is for instance the defined geometry of the sheet metal. Therefore, pre-machining work of the sheet metal at a feed rate of 80 m/min is necessary. The following article describes which manufacturing processes, how and why match the respective application purpose.

**Key Words:** Milling, Edge Preparation, HSC, Sheet Metal

## 1. INTRODUCTION

The priority objective of the Collaborative Research Centre (CRC) 666 “Integral sheet metal design with higher order bifurcations” at Technische Universität Darmstadt is to research both new manufacturing processes, like linear flow splitting of sheet metal and the combination of different manufacturing processes which have not been researched in such an arrangement concerning their process capability so far. For the investigation and the testing of these new concatenated manufacturing processes, the CRC 666 prepared the plant shown in Figure 1.

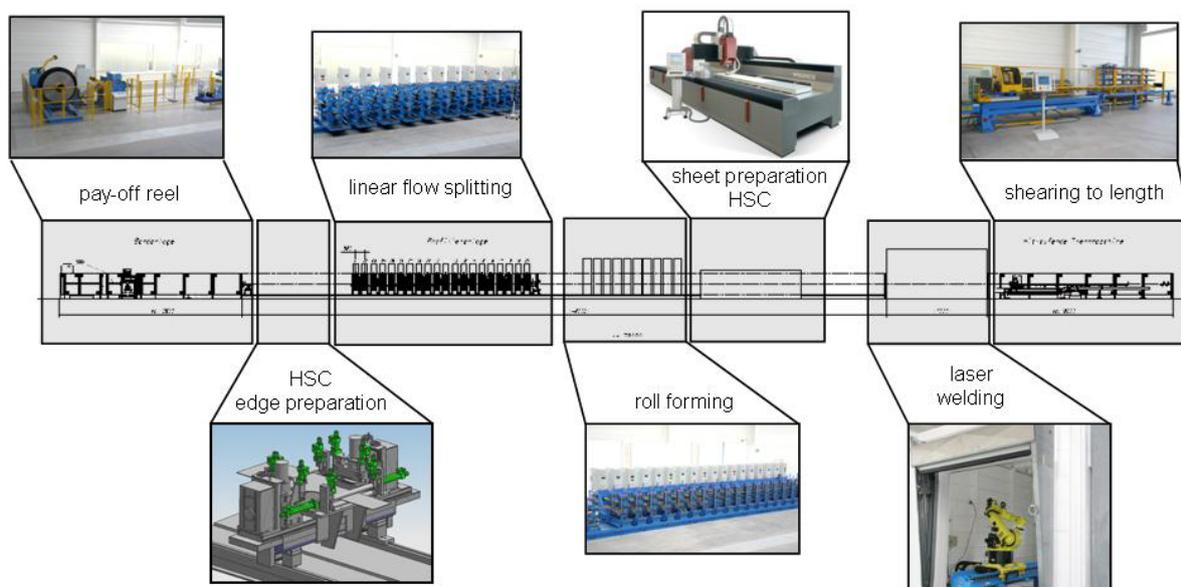


Figure 1: Test facility in the CRC 666 at TUD for the manufacturing of multi-chamber profile to be composed of steel.

Linear flow splitting is a deformation technology method, which is new in view of sheet metal. In first investigations, it was proved that with sheet metal design of higher order bifurcations (see Figure 2), new fields of application for flat semi-finished products could be made available through the adding of concatenations [1]. The principal task of the CRC 666 is to further investigate these processes and to develop such fields of application. It became very early obvious that there are new requirements for the relevant processes. A linear flow splitting e. g. with a high quality final product requires an optimally defined, geometrical flat semi-finished product.

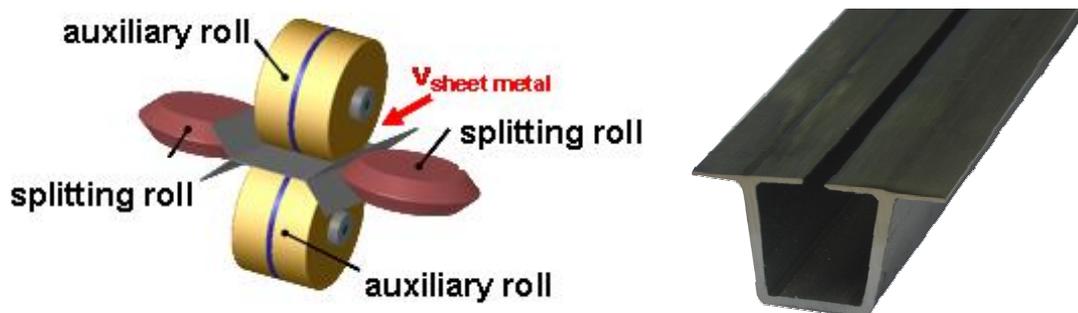


Figure 2: Principle of linear flow splitting and example of a manufactured profile.

The edge preparation of flat semi-finished products is one of the main tasks of the partial project B3 at the Institute of Production Management, Technology and Machine Tools. The purpose of the subproject B3 is to cut the metal strips at a feed rate of 80 m/min in an economic way. At the moment, the work piece material ZStE500 with a material thickness of 2 mm, which is particularly suitable for linear flow splitting, is used.

The machining step starts with the pay-off reel, which is responsible for supplying and delivering the material before preparing at the sheet metal straightening machine. The first module in the plant is the edge preparation machine, followed by a rack of linear flow splitting modules. At the third position, the racks of the roll forming are attached. After them, both the HSC of sheet metal and the laser welding are arranged. Shearing to the defined work piece length finishes the manufacturing process. This combination of different manufacturing processes allows the production of open profiles of linear flow splitting by roll forming. Consequently, it can be talked of hollow section when the laser welding closes the open profiles. The pay-off reel cuts the endless profiles to their respectively size. The arrangement of the manufacturing processes is adjustable, which means that each part of the plant can be changed for maximum efficiency and higher sequential programs.

## **2. DEFINITION EDGE PREPARATION OF SHEET METAL**

Actually, edge preparation is defined to prepare joining by creative forming as well as edge contouring e. g. cutting or rounding edges [2]. The process of linear flow splitting depends on the width of the plates and the geometry of the edges. The DIN 10140 includes some arrangements, which have to be added by preliminary skelp edge preparation. The welding of skelp edge needs a defined skelp edge, which depends on both the kind of the welding and the dimension of the plates. Usually, the arrangements contain the chamfers of band edges. By increasing the surface of the plate, both the easily energy input in the welding process can be realized and at the same time, the uniformly joining of the assembly component. The skelp edge preparation is anticipated for pipeline fabrication for delivering gas and fluid at which the thickness of the material can be up to 50 mm. At the moment, this happens with a rate of production of 3 to 35 m/min [3]. The CRC 666 makes use of skelp edge preparation to reduce the inaccuracies, which can be improved by the linear flow splitting (see Figure 3).

**Reasons for the edge preparation**

- Defined edge geometry for linear flow splitting is necessary
- Higher contouring accuracy and defined edge geometry for preparation of the weld seam
- Adjustment of shape deviation after the linear flow splitting

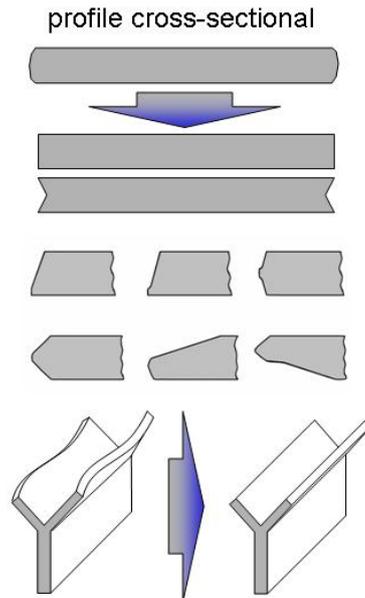


Figure 3: Applications of strip edge trimming within the CRC 666 [Picture of the weld seam geometry: Linsinger].

Furthermore, the edge preparation can be used for applications of fitted metal strips. The developed technologies of flexibly roll forming blank were utilised as yet at the Institute for Production Engineering and Forming Materials (PtU) at Technische Universität Darmstadt (see Figure 4). After reaching the aims of the project, both a continuous and coil process could be the further arrangement.

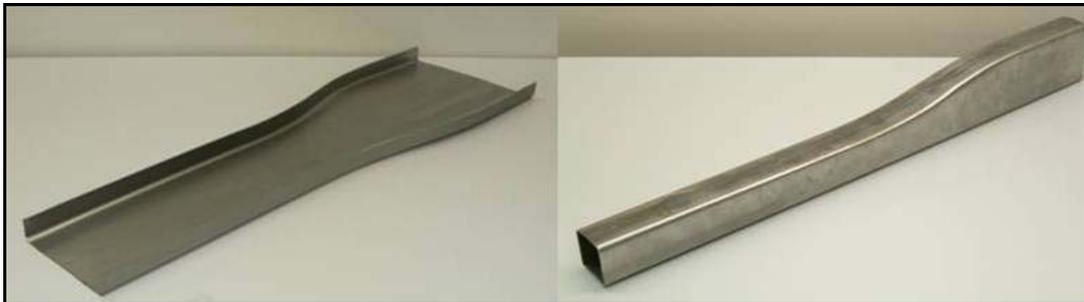


Figure 4: Treatment of blank before and after the flexibly roll forming process [source: PtU].

The chaining of the new linear flow splitting process and the flexibly roll forming could be the next contract at the CRC 666 and thus being better prepared for preferences of strip edge trimming.

### 3. THE MANUFACTURING PROCESS OF STRIP EDGE TRIMMING

#### 3.1 Shearing and slitting

At slitting, the shears are used as a roller for endless running cuts. Due to directing a rectilinear motion of the double cutting edges together, the rollers produce a straight cut (see Figure 5).

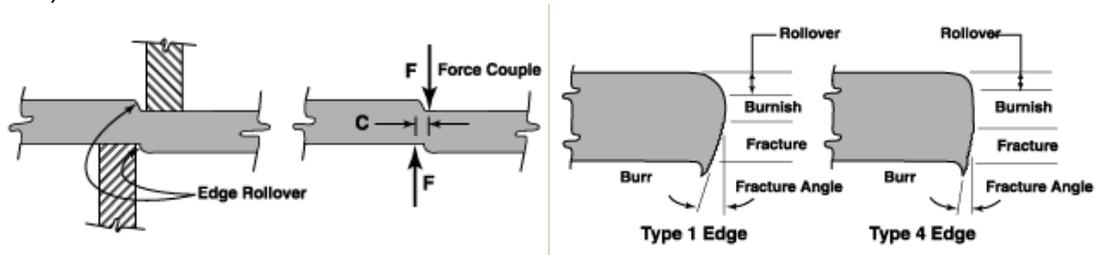


Figure 5: Skelp edge preparation through slitting, exposition of the cross-section [source: [www.thefabricator.com](http://www.thefabricator.com)].

The slitting process is a combination of both cross and drifts cutting edges [4]. The forces, which occur at rotary cutting are very high and thus require a defined rack to stand up. Shears enable only straight cut. The cut part of the material depending on its dimension has a rigid form, which is difficult to handle because of the high feed motion of the plate. Due to the high risk of fracture, the prepared edges are not suitable for further processing steps like welding or cracking. The machining quality, which can be reached, is too low for the CRC 666. Usually after the shear cut a trimming is necessary [5]. In principle, the manufacturing process of fitted metal strips can be realised, but the varying strip widths could be critical for the process.

#### 3.2 Thread cutting

The thread cutting of skelp edge preparation can be used for preliminary work of welding in a sheet range of up to 6 mm (Figure 6). The outcome of this is that sheet metals up to this thickness can be welded together easily. Furthermore, the material removed is not manageable at a sheet thickness of  $t = ap > 6$  mm and feed rates of  $ae > 0,50$  mm. Normally, the process capability of manufacturing process is negatively affected by thread and flow chips [6].

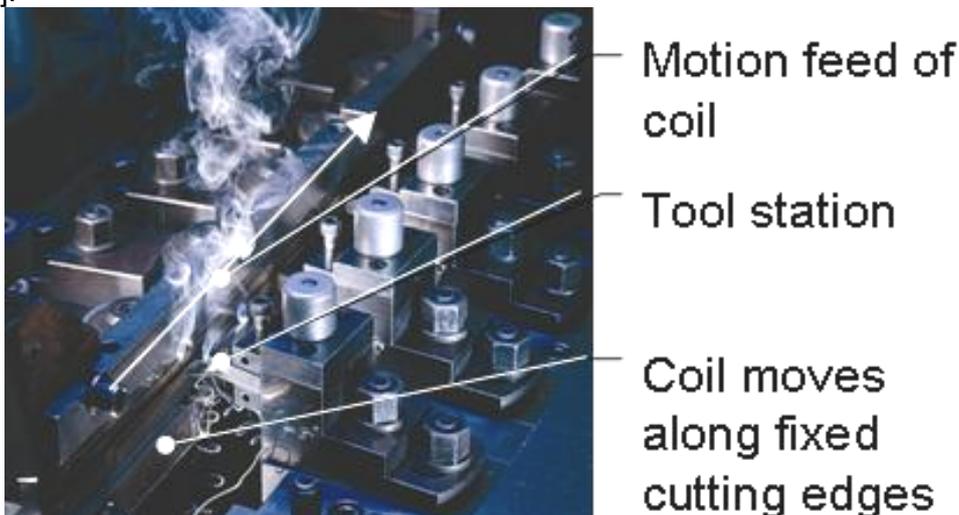


Figure 6: Thread cutting of a metal strip [source: Hugo Vogelsang GmbH].

With the thread cutting process, infeed of 350 m/min can be reached. Only a limited band of defined geometries is suitable for manufacturing. The sheet metal runs through to one or more of the HSS-cutting tools or inserts. The advantage of indexable carbide insert is applied for milling and turning. They are available in different geometries adapted to the cutting task. Many types of both the cutting materials and the coating allow an accurate preparation of the process depending on the raw material [6]. By the thread cutting process, there can be produced surface quality in the range of an average surface finish of  $R_a = 0,4 \mu\text{m}$ .

To produce fitted metal strips, no dynamic infeed orthogonal to the feed direction of the sheet metals is possible. Only a re-adjusting to compensate tool wear is feasible. The maximum depth of cut of each shear depends on the number of tool stations. Therefore, many tool stations should be used for high metal removal rates. Typically, the tool stations are arranged once at the beginning and after the intervention on the sheet metal, only small re-adjustments are possible.

### 3.3 Laser cutting

Laser cutting becomes more and more important. The high velocity and the repeat accuracy of CNC systems combined with the very fast and accurate laser cutting process are laid off the potential of rationalization. Due to the geometry of the laser beam, the cutting edge can only be a straight line upright to the surface of the sheet metal. However, it is possible to produce defined band geometries by dynamic infeed, e. g. the production of fitted metal strips. There are still some thoughts about both the metal strips and the cutting parts of sheet metal, which accrue at the end of the working station with the same length and velocity (Figure 7).

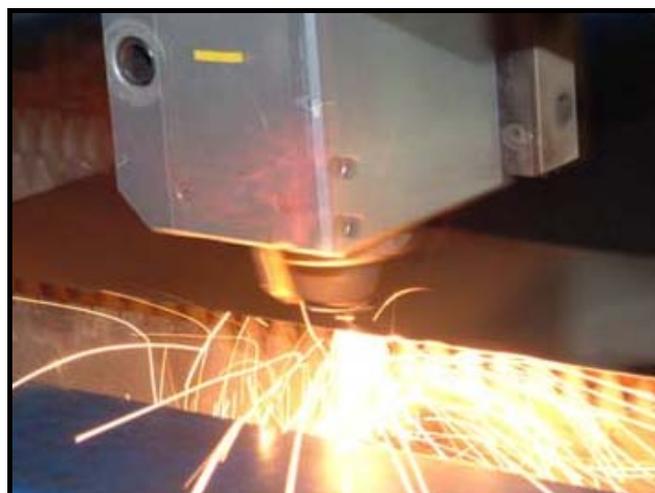


Figure 7: Laser cutting [source: <http://www.schraeder-gmbh.de>].

The preparation of steel by that method has some more disadvantages. By the high supply of energy, thermal warp is evolved at the borders of the edge. In addition, structural changes emerge in the range of the cutting edge, which makes the linear flow splitting process impossible. At a sheet thickness of 2 mm, there can be reached feed rates of up to 30 m/min [7].

### 3.4 Milling edge preparation

Nowadays, the milling edge preparation is commonly used for specially defined band edges in a range of 6 mm to 200 mm. The field of application for the milling process is especially there, where subsequent processes call for tension or heat distortion free surfaces. Just like thread cutting, milling can be used to produce any edge geometry by appropriate cutting edge geometry (Figure 8). At the moment, it is inserted in processes with a high rate of swarfs by discontinuous cut to simplify the evacuation of the produced chips. Typical applications are found in the shipping, pipeline, and the wind energy industry [2].



Figure 8: Examples for strip edge milling machine [source: Linsinger GmbH].

An important advantage for the milling skelp edge preparation is the kinematic active principle of milling. The discontinuous contact of the shear with the material has two effects. One of them is to remove the excess material and the other is to cut the excess material in equal parts called swarf. So, this machining differs from other processes. The swarfs have a very manageable form. Moreover, milling admits a dynamic infeed, which means that the infeed crosses the flow direction of the metal strips during the feed motion to produce fitted metal strips. The maximum contact width depends on the cutter diameter and also on the rigidity of the clamping of the sheet metal. The feasibility of the maximum contact width could be realized until the half cutter diameter.

## **4. DISCUSSION**

The skelp edge preparation using a high speed milling process is characterized in a special way, i. e. with special process dynamics. As the velocity of the metal strip is given by the system of linear flow splitting for producing higher order bifurcation both controlled metal forming rates and high productivity are required, consequently a highly velocity for the feed rate is necessary for the milling process. Both the cutting speed  $v_c$  as the feed per tools  $f_z$  have to be set to values within a very small process window. If one assumes a changing velocity of the metal strip within the metal forming system, a tool with an adjustable diameter would be ideal.

Since the cutting speed is adjusted for an continuous process for the optimal tool life, the speed is a given value. As a result, there are only two parameters left for realising and optimising the process: the cutter diameter  $d$  and the pitch  $z$ . According experts from industry, in these applications special tools with diameters of up to 1500 mm and of up to 90 teeth are used.

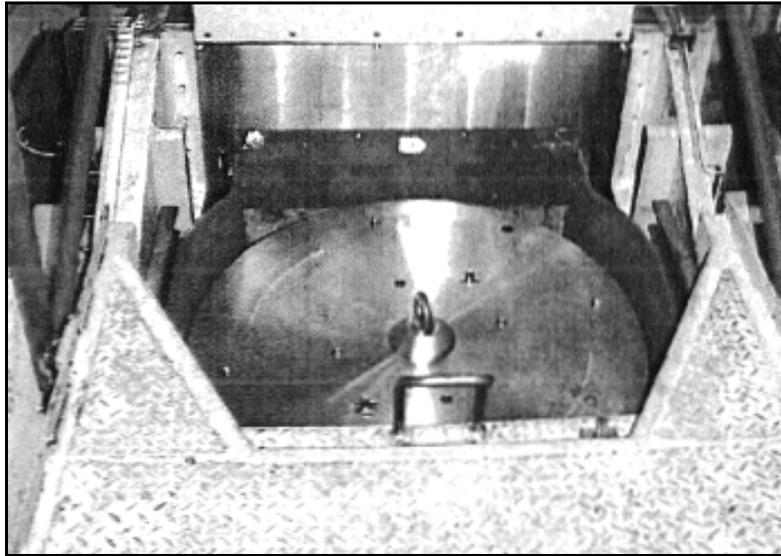


Figure 9: Skip edge cutter head at its site [source: SMS-Meer AG].

For the pipeline process, tool changing has to be avoided because the coils are used for the manufacturing process, which are welded together from the endless raw material. Labour-intensive tool changes can be moved in the non-productive time to guarantee the endurance by using very thick indexable insert and changing the acceptable maximum of the flank-wear land width to up to 1 mm. In Figure 9, the cutter head has eye bolts for lifting with a crane. The entire pipeline production line has to stop during tool changing at the skelp edge preparation machine. This leads to high technical problems for the endless welding process and a high rate of rejection.

But a solution would also be a common tool changing system as an acceptable alternative. Here, the HSK interface linked with the HSC-technology should be mentioned. The HSC-technology makes high cutting speeds possible and decreases the cutting forces at the same time. This has a positive effect on the tool wear and thus also on the tool life.

The recent trend from motor control gear coupled drive spindles to high-speed frequency allows a high number of revolutions per minute. The integrated HSK tool fitting in the direct drive motor spindles enables a quick tool change. Nowadays, the proceedings in the automation allow a chip-to-chip time smaller than two seconds [8]. The combination of HSC and HSK allows attaching a new manufacturing strategy, which generates rationalisation potential in the skelp edge preparation and an alternative for heavy motor transmission units. Furthermore, the issue of the process limits for skelp edge preparation in consideration of stock removal volume and cutting force was not answered with a science-based contribution yet. Through the metal strip velocity connected with the high wrap angle, the force at the cutter becomes huge, which can be conditionally intercepted in the feed motion. In order to minimise these forces, there are constructed machines whose cutters are twisted and arranged in the machining plane at a defined angle of the sheet plane. However, this arrangement prevents the possibility of producing high feed rates. Therefore, it is usually applied at a huge swarf volume, but small infeed width and thus at large sheet thickness [9].

Another insufficiently solved problem arises for the analysis of the development of burr at the band edge during the milling preparation. The possibilities to influence the process are restricted to the cutting parameters speed  $v_c$  and feed per tooth  $f_z$  as well as the chip geometry, which is defined by the position of the milling spindle and the position of the cutting plate in the Z-axis, the variation of the angle at the cutting tooth, the lip clearance angle, the sharpening angle and the rake angle. Moreover, the burr formation can be influenced by the micro geometry of the cutting edge by adding a cutting edge rounding or cutting edge bevelling. Corresponding analyses are executed already at the PTW for cutting down the additional deburring process.

## 5. CONCLUSIONS

As a conclusion, the following table gives a comparison of the manufacturing processes for skelp edge preparation in consideration of all kinds of possible versions of the edge geometry, the handling of the removed material, the surface quality and the productivity. As shown in the table, milling has satisfactory properties under all circumstances necessary for CRC 666 and is therefore the preferred strategy.

Table I: Comparison of the edge preparation methods [9].

preparation methode	variation of the edge geometry	handling of the removed material	surface quality	productivity
laser/gas cutting	-	-	-	-
shearing	-	-	-	+
thread cutting	+	-	+	-
milling	+	+	+	+
caption	satisfying	+	insufficient	-

Particularly in view of the needs and the assembly of fitted metal strips, high-speed millings have emerged as an appropriate process for the given CRC purpose. The given potential to reduce tool-changing time and increase primary processing time leads to an efficiency gain for the edge preparation. The aimed range of sheet thickness of up to 6 mm within the CRC 666 was not subject to edge milling up to now.

The reached technology parameters in other HSC-areas as well as the fact that HSC are the state of the art in many applications assume that an improvement in the range of skelp edge preparation is possible. The aim to reach a feed speed of 80 m/min and machining an entire coil of sheet metal using tools with small diameters and a small number of carbide tools is realistic. A corresponding solution for involved defiances like an increased inclination to vibrations and the achievement of economic cutting distance are analysed at PTW. The development of special tool geometry for high speed milling of band edges is the main focus at present. Special carbide inserts for edge preparation for the production of fitted sheet metals are likely to come in the focus of interest with the second and the third project stage.

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