VeraCAD Technology Chat	
Title:	**Rolling of Aluminum material with VeraCAD**
Type:	**Advanced technology**
Version:	**All versions of VeraCAD**
Language:	**English**
Date:	**16.7.2019**

Rolling of Aluminum material with VeraCAD

This article explains the advantages of using Aluminum in the forging industry and introduces some special requirements of Reducer Rolling for Aluminum.
Focus of this article is the process of reducer rolling and designing tool segments with VeraCAD.

Lightweight, high-strength and extremely reliable advantages of Aluminum forged parts

The use of Aluminum Forging parts in the automotive industry is a contribution to reduce, weight, fuel consumption and CO_2 emissions. Especially in the case of safety parts, forging shows significant advantages in performance of the components, compared to the various casting processes. The processes are under ongoing consistent research and development, this will further improve procedures and reduce costs.
Density of Aluminum is much lower as steel (Aluminum 2.7 g/cm^3, Steel 7.85 g/cm^3). Therefore, components made from Aluminum can save 60 % for weight, but because the stability does not reach the stability of steel components, Aluminum parts often have bigger dimensions or cross sections. Finally, the typical weight savings are 50 %. Given a difference in consumption of up to 0.5 liters of fuel per100 kg of additional vehicle mass, the use of Aluminum can achieve a substantial contribution to reduce consumption and CO_2 emissions (this topic partly was translated from the article in SchmiedeJOURNAL March 2012, Page 25, Dipl.-Ing. Klaus Vollrath, Aarwangen, Schweiz; Dipl.-Ing. Frank Severin, Hagen).

Reducer Rolling of Aluminum – The process

Rolling of Aluminum in practice has a lot of special requirements. This section will discuss the specifics of the rolling process.

Raw material

Normally the raw material are round billets, which were previously sawn on suitable length. The cut surface is usually rough and has a burr on the edge. If the ends of the stock are later inside the forging part, this burr cannot be accepted. Aluminium forgings are very sensitive, if there are defects on the surface. Therefore, this burr must be removed beforehand. To create a phase at the edge, another cutting operation is necessary.

Temperature

The temperature range for Aluminum is very narrow and is usually 500 °C to 520 °C. Beyond this temperature melting effects will appear. In order to keep the temperature within this small range, the tool segments must be heated. The tool surface is heated to 250°C before the rolling process starts. This is normally done with a gas flame. In addition, the tempera-

ture must monitored and controlled. Normally a camera sensor will measure up the tool surface temperature and switch on the gas flame if necessary.
Later during the rolling process, the heat flow from workpiece to tool is enough for keeping the tool surface on the required temperature. Additional heating is required only if the rolling process is interrupted for some time.

Cooling of the machine

The heat of the rolling segments of 250 degrees goes into the shaft and into the bearings of the machine. The bearings usually cannot stand this. Therefore, the shaft and the bearings are cooled, which requires an additional water-cooling system with a pump.

Burning layer

During the rolling process, some particles from the Aluminum surface will melt and stick firmly onto the surface of the rolling segments. This burnup layer will not automatically spall if the next part is rolled, instead this layer will damage the surface of all following pieces. It is necessary to get rid of this pollution. You could stop the rolling process after some parts are rolled and remove the layer manually, but this method is not practical.

Spraying the tools

To avoid the burnup layer on the tool surface, the tool segments are sprayed with a film of lubricant after 3 or 4 parts were rolled. Normally in reducer rolling we do not lubricate, because the high friction between Workpiece and tool segment is important. Because of high friction the transport of the part is guaranteed. Depending on the deformation, the force with which pulls the part forward can become too small and the rolls slip on the surface instead of moving the part forward. One consequence of this is, that the tapered transitions on the Aluminum part must be made flatter than that of steel parts.
The spraying of the tool surface can be done with FUCHS lubricant for Aluminium. It is necessary to do it after each 3 or 4 parts. Otherwise the burnup layer will weld onto the segment surface.
Again, this cannot be done manually, and an automatic spraying system is required.

For more information see the video of Schubert Group in Ennepetal, Germany. It show Aluminum rolling of a refurbished Eumuco rolling machine with 370 mm and automatic gas heating, cooling system and spraying system.

Reducer Rolling of Aluminum – The tool design

In general, the design of Reducer Roll Tool for Aluminum is very similar to the design for steel. But there are a few details that are different. This chapter will discuss the special settings and design rules for Aluminum.

Material settings

First do the necessary settings in Calibration Plan > Raw Material.

Raw Material	
⊟ Dimensions	
Type	Circle
Diameter	40 mm
Scale thickness	0.10 mm
Thermal expansion	1 %
Thermal contraction	0 %
Material density	2700 kg/m³
Cross-section area (cold)	1244.3 mm²
Cross-section area (warm)	1281.9 mm²
Raw material (cold)	121.8 mm
Raw material (warm)	123.6 mm

Set the density for Aluminum 2700 kg/m^3. This will not affect the geometry, but the total weight of the billet. In View information the total weight is calculated using the density.
Set the "Thermal expansion" to 1 %. In many features of VeraCAD Software, there is a calculation between cold and warm condition. This factor is used to make all calculations between cold and warm.
Set "Thermal contraction" to 0. The value for thermal contraction is required, if the material gets some cooling during the rolling process.
As previously explained, the temperature range for Aluminum is very small. Therefore, the material does not loose temperature during rolling. Set the thermal contraction to 0.
Set "Scale thickness" to 0. Forging for steel normally is done with 1200°C. Heating is with gas or induction. The surface will oxidize and build a layer of scale. The scale thickness is between 0.1 mm and 1 mm, depending on the heating method.
VeraCAD will calculate the cross-section area without the scale layer. In VeraCAD's calculation chain the scale will flake off before pass 1 is processed.
Aluminum does not build a scale layer with an important thickness. Therefore, this value is 0.

VeraCAD's thermal expansion and dimension chain.

d_0 = Diameter of raw material in cold condition [mm]
e = Thermal expansion from cold condition to furnace temperature [%]
s = Thermal contraction during rolling [%]
ox = Thickness of scale layer (oxide).
d_w = Diameter of Finished part (last pass) in warm condition

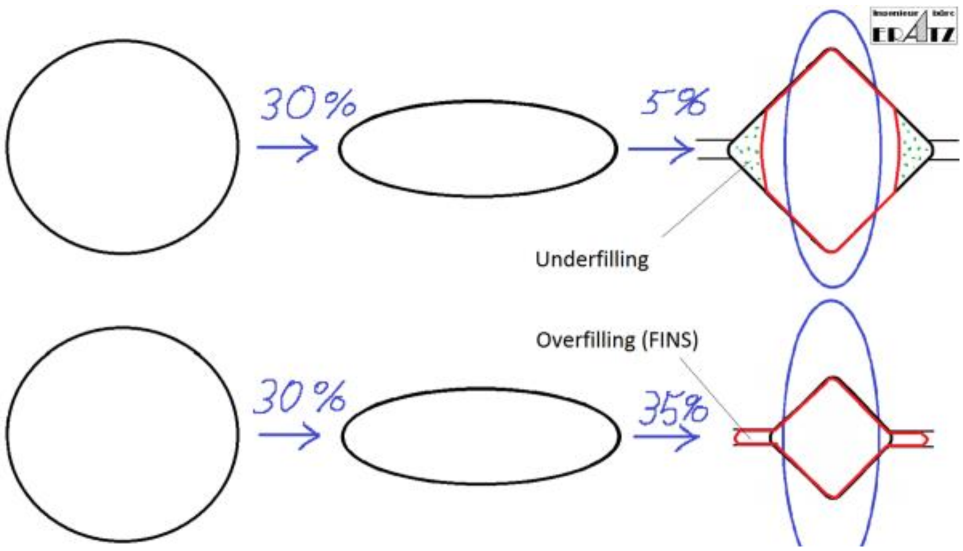
$$d_w = d_0 * (e - s) - 2 * ox$$

Calibration plan

For Aluminum you should follow the same “Golden Rules” during project design, as it is necessary for steel. See the paper “Golden Rules”.
Because of Aluminum has a very high potential for deformation, the reduction rate in one pass can be higher as for steel. For steel the reduction rate in one pass is limited to 40 %. For Aluminum it can be up to 50 %. That is a cross section can be cut to the half in one pass. But VeraCAD does not have a special database for calculating the Oval shape for Aluminum. The Oval shape becomes very flat (wide Oval with narrow height), if the reduction rate is close to 50 %. To avoid the very flat ovals, we recommend limiting the reduction rate to a maximum of 45 % for one pass.

Linked reduction

In reducer rolling the calibration sequence normally is
CIRCEL - OVAL – CIRLCE – a.s.o.
That is, after a “Spreading” cross-section a “non-spreading” cross-section will follow. The non-spreading cross-section has a reduction rate that is linked to the previous reduction rate. In this case reduction in pass 2 is linked to reduction in pass 1. This will guarantee a 100 % filling in pass 2. (CIRCLE). The illustration below shows the link mechanism for reduction rates. If the reduction in pass 2 is too less, this will cause underfilling, if it is too high it makes overfilling (fins). That is, the correct reduction rate for 100 % filling is somehow between these values.



For steel material the rule for linked reduction in the non-spreading cross-section is as follows:

P1 = Reduction in pass 1 from Circle to Oval
P2 = Reduction in pass 2 from Oval to Circle or Square

P2 = 0.80 * P1 if pass 2 is Circle
P2 = 0.85 * P1 if pass 2 is Square

For Aluminum we recommend reducing these values. For Aluminum use these values:
P2 = 0.75 * P1 if pass 2 is Circle
P2 = 0.80 * P1 if pass 2 is Square

Explanation
On one side Aluminum has a high potential for deformation and therefore can accept high reduction rates. On the other hand, Aluminum has extraordinary problems, if the surface has any marks, defects or fins. Such surface defects are not reversible in further deformation. In fact, the defects will preserve until the forging is completed and can be found on the final part.

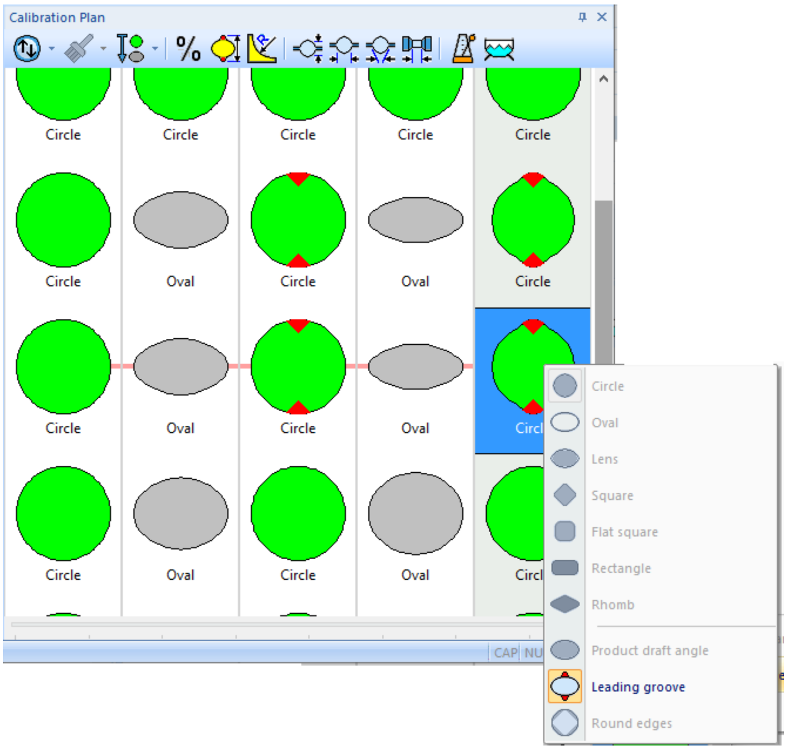
It is essential to keep the surface free from such defect and fins. We recommend accepting a little bit of underfilling to avoid this danger of generating fins, if the reduction rate in pass 2 is too much.

Leading grooves / Twisting

One important rolling defect is twisting of the part. For Aluminum there are many reasons, why the danger of twisting is higher than for steel material.

- Aluminum is much weaker than steel.
- Aluminum parts are often very long (steering parts).
- High reduction rate up to 45 % produce very flat Ovals.
- The lubrication of the tool segments reduces the friction and the cross section can slip.

This are reasons, why a cross-section can twist much more quickly, if we do the rolling with Aluminum. We already had projects where one cross-section twisted about 45 degree compared to its neighbor. If this happens the normal consequence is, that the part is damaged and unusable.
We must take steps to avoid this twisting. This is normally done by using “leading grooves” behind each Oval and Square shaped cross-section.
Follow “Golden Rule” no 4 and apply leading grooves where necessary.
Use right mouse button to apply the “leading groove”.



Draft Angles / Flash corner Radius

In “Golden Rule” no 5 and 6 we apply Draft Angles to the impression and individual flash corners radius for each cross-section.
As mentioned earlier, we must take special action to avoid defects, marks and fins. A design with a smooth and harmonic segment surface can help to achieve this aim. We will make the draft angles following the rules in “Golden Rule no 5” and make the flash corner radius bigger as for steel processing segments.
Do not forget do make the impression leading edge radius a bigger as for steel.