VeraCAD Technology Compendium

Title:	**Reduction Rates – General rules – Best practice – Golden rule no. 3**
Type:	**Basic Technology**
Version:	**all Versions**
Language:	**English**
Author:	**Dipl.-Ing. Hermann Eratz, ERATZ-Engineering (Germany)**
Date:	**2020/11/19**

This article explains:

- Theory of cross-section reduction
- Number of passes
- Basic considerations for Reduction Rates
- Rule for Reduction rates.
- VeraCAD Project example

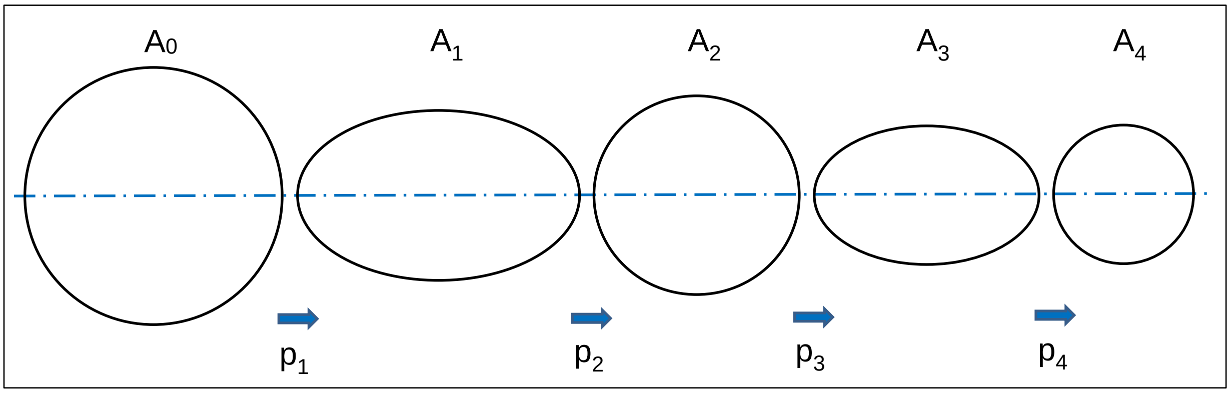
The article gives an insight into the technological context of reduction rates and is intended to help, finding suitable number of passes for the design of roller parts. Reduction rates are essential for correct cross-section filling and avoidance of rolling defects.

1. Theory of cross-section reduction

Reducer rolling generally serves to produce pre-profiled bars, which then come as close as possible to a required mass distribution. Therefore, reducer rolling is particularly well suited to produce long parts with harmonious transitions. These rolled parts are mostly preforms and only in rare cases are finished parts with small tolerances.
During reducer rolling three things will happen simultaneously in one cross-section:

- The cross-sectional area is reduced - this is desired.
- The rolled part gets longer – this is a consequence of volume consistency.
- The cross-section is becoming wider (spreading) – we accept this.

The amount of possible reduction in one pass is between 0 and 40% (for steel) or 0 to 45% (for aluminium). If cross-section area is reduced, normally the cross-section shape will change. As more deformation(reduction) is required as more the cross-section will spread on both sides. If more than one pass is necessary (total reduction more than 45 %) the standard calibration sequence is a chain of Circle and Oval shapes (s. Pic 1).



Picture 1: Calibration sequence with 4 passes and high reduction.

The equations to calculate cross-section area are:

$$A_1 = A_0 \cdot (1 - p_1)$$
$$A_2 = A_1 \cdot (1 - p_2) = A_0 \cdot (1 - p_1) \cdot (1 - p_2)$$
$$A_n = A_0 \cdot (1 - p_1) \cdot (1 - p_2) \cdot \ldots \cdot (1 - p_n)$$

The equation for total reduction after n passes is:

$$p_{total} = 1 - \frac{A_n}{A_0}$$

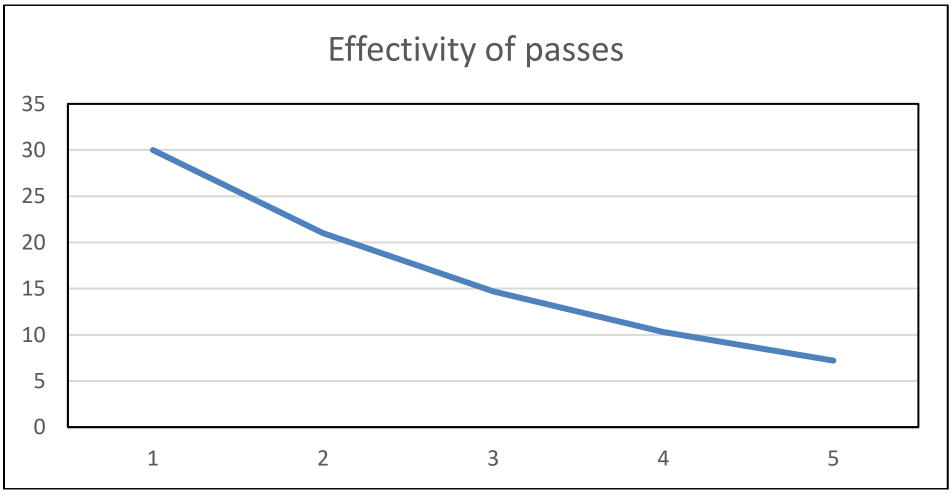
Example:
A_0 = 1000 mm²
A_1 = 1000 mm² *(1-0.3) = 700 mm²
A_2 = 700 mm²* (1-0.3) = 490 mm²
p_{total} = 1 – 490 mm² / 1000 mm² = 51 %

2. Number of passes

Now we can calculate total reduction for 1 to 5 passes and the difference in total reduction from $pass_i$ to $pass_{i+1}$. We will do this for an example with same reduction rate of p_i = 30 % for all passes.

Number of passes	1	2	3	4	5
Reduction one pass	30 %	30 %	30 %	30 %	30 %
Total reduction	30 %	51 %	66 %	76 %	83 %
Increase of reduction	30 %	21 %	15 %	10 %	7 %

Obviously the first pass is most effective, and the last pass is most ineffective (pass 5 gives only 7 % of additional cross-section reduction). If we sketch a diagram of “effectivity in reduction” it looks like this.



We find that the effectivity (ability to reduce total cross-section area) of passes becomes less with more passes. Therefor it is better to do the project with the minimum number of passes. There are more advantages to use a lower number of passes:

- The process time is shorter
- The tool costs are reduced
- The process stability is better (fewer rolling defects)
- Less length problems will make less fins
- Machine width can be smaller

3. Basic consideration of reduction rates

Now we will analyse a calibration sequence of CIRCLE – OVAL – SQUARE. The first reduction rate CIRCLE to OVAL is 30 % in all cases. That is, we will receive the same OVAL in all 3 cases. But the second reduction rate OVAL to SQUARE is 12/40/25.5 %. Of course, the final square will have different size.

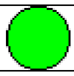
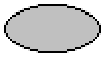
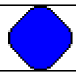
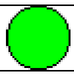
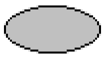
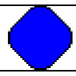
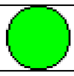
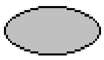
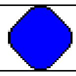
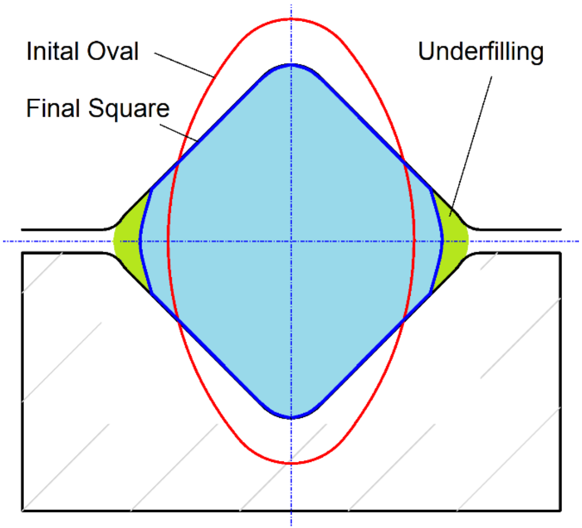
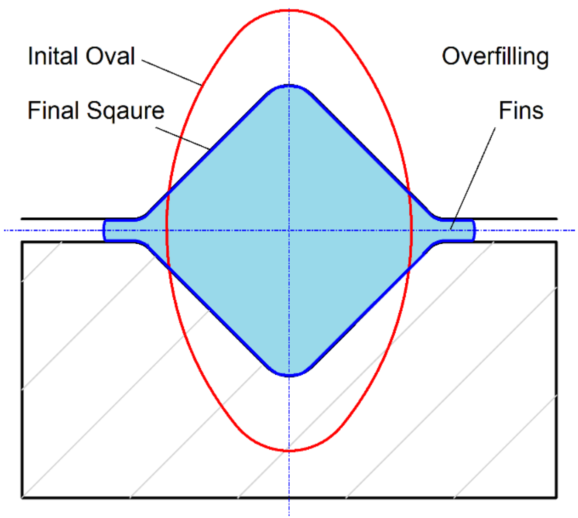
	Initial cross-section	1	2 behind Oval
		30 %	12 %
1			
		30 %	40 %
2			
		30 %	25.5 %
3			

Table 2: Circle-Oval-Square with different reduction rates in pass 2.



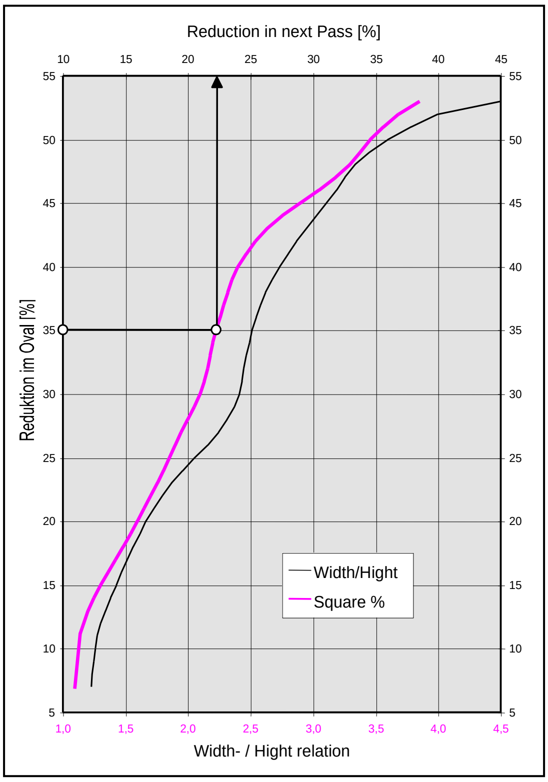
Pic 2: Reduction p_2 = 12 % - Underfilling



Pic 3: Reduction p_2 = 40 % - Overfilling

Both calibration sequences will not produce a 100 % filling of the square. The Oval-Square with p_2 = 12 % creates underfilling and Oval-Square with p_2 = 40 % produces “Fins”. The underfilling on one hand is not a critical rolling defect. Especially, if underfilling happens not in the Finished part. But if we have further passes after the underfilling, normally the under-filling makes length problems. The volume, that is missed in the cross-section must escape in length direction (volume constancy!). That is, the part becomes longer than planed from the

design. Next pass will have length mismatch and normally will create laps, fins or marks in some sections. Therefore, underfilling and overfilling both are severe rolling defects.
We must determine one reduction rate that will lead to a perfectly filled cross-section (100 % filling no underfilling no overfilling).



Many years we have used data tables from EUMUCO (today SMS-Meer). This tables are very old and are based on experimental and empirical knowledge. Tables like the one on right side were used to determine the required reduction rate for 100 % filling of the square. First follow the reduction rate in oval cross-section on a horizontal line and find intersection with the magenta line. Next read the reduction rate for next pass (square) on the upper edge of the diagram.

In recent years we had some diploma workers who have made research work for that topics. In fact, the 100 % filling problem depends on many parameters. Main influence will have:

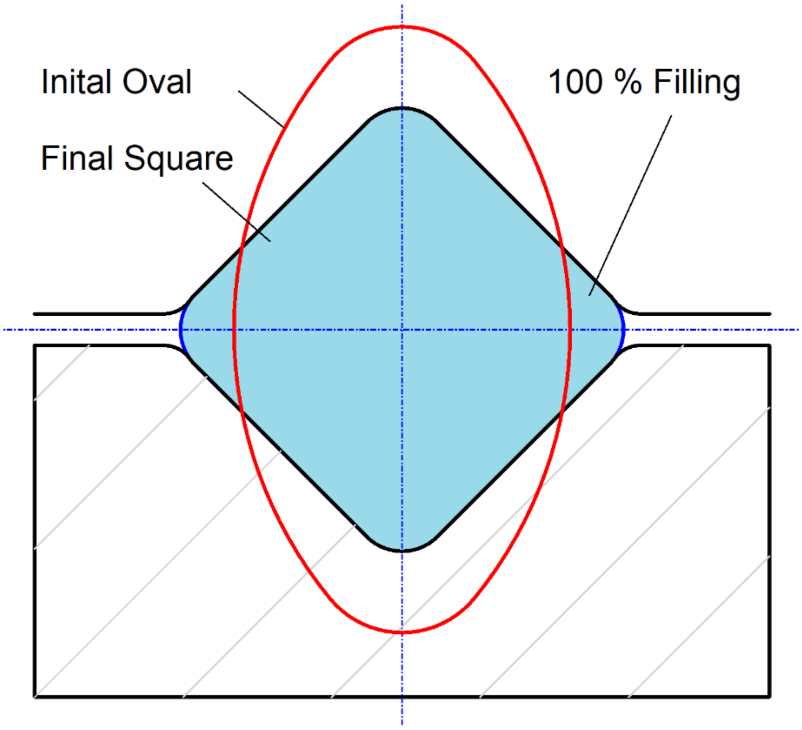
- Reduction rate
- Type of calibration (shape)
- Material (alloy)
- Friction
- Length of reduced section
- Machine size

The research work was done by students from Taiwan. The results are in Chinese language and are not integrated in VeraCAD Software. This research work is an open topic and is one of the most important milestones in the aim to improve the automated design of reducer roll tools. A bigger research package with the Title “New database for Reducer Rolling” has been described, but so far was not executed.

4. Rules for reduction rates

Today we use some simple equations to find the 100 % filling reduction rate behind the Oval cross-section. If first pass is Circle to Oval or Square to Oval with reduction P_1 the next pass should have reduction rate according to:

$$P_2 = 0.80 \cdot P_1 \qquad \text{(if } A_2 \text{ is CIRCLE)}$$
$$P_2 = 0.85 \cdot P_1 \qquad \text{(if } A_2 \text{ is SQUARE)}$$



Picture 4: Reduction in Oval-Square with p_2 = 25.5 %

The square in picture 4 shows perfect cross-section filling and follows the rule
$P_2 = 0.85 \cdot P_1 = 0.85 \cdot 30\,\% = 25.5\,\%$

For practical work in VeraCAD you should prepare an Excel chart like shown on the right side. “Reduction Helper” has 3 columns.
First column is reduction from circle or square to oval. Second column shows reduction, if the shape behind the oval is a circle. This column is reduction for oval multiplied with 0,8. Third columns shows reduction, if the shape behind the oval is a square. This column has factor 0,85.
If the project has 4 passes, Reduction helper is applied 2 times. First for Pass 2 and then for pass 4.

Reduction Helper		
Pass 1	**Pass 2**	**Pass 2**
Type OVAL	Type CIRCLE	Type SQUARE
1	0,8	0,85
2	1,6	1,7
3	2,4	2,55
4	3,2	3,4
5	4	4,25
…	…	…
36	28,8	30,6
37	29,6	31,45
38	30,4	32,3
39	31,2	33,15
40	32	34

5. VeraCAD-Example

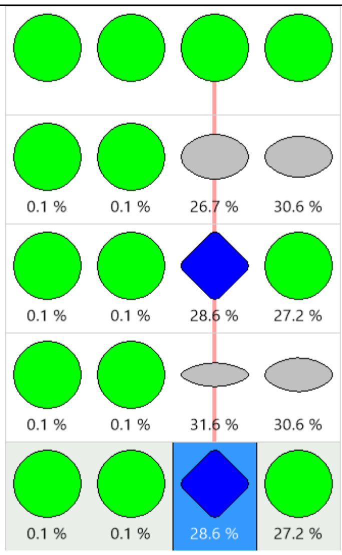
The VeraCAD sample is a simple part with 4 passes. The raw material has circle shape. Finished part has 2 cross-sections with a total reduction of 74.4 % each. This requires a 4-pass calibration sequence. Cross-section 3 has CIRCLE-OVAL-SQUARE-OVAL-SQUARE calibration and cross section 4 has CIRCLE-OVAL-CIRCLE-OVAL-CIRCLE calibration. After setting the cross-section shapes (Golden Rule 2) the reduction rates calculated by VeraCAD for the initial project are shown in the middle.

We apply “Reduction Helper” 2 times for cross-section 3. First, we set the reduction in pass 1 to 32.4 %. According to the table with column square (0.85), the next reduction will be 27.5 %. We can set reduction rate in pass 3 to 30 %, which will automatically set reduction rate in pass 4 to 25.5 %. This is a match according to “Reduction Helper”. If it does not match, we go back to the oval shape and modify the reduction here. See the result in the picture on right side.

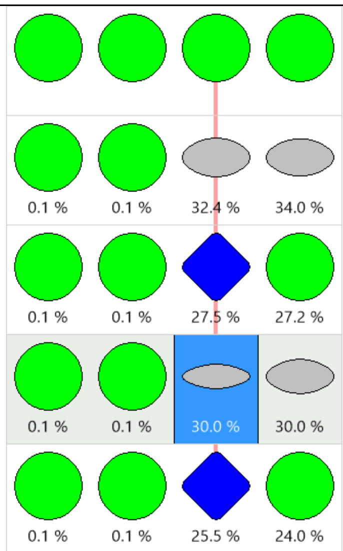
Then for cross-section 4 we apply “Reduction Helper” 2 times. Our reduction rates for pass 2 and pass 4 will come from column “circle” (factor 0.8). The result is 34%-27.2%, 30 %-24%.

Notice hat in both cross-sections (3 and 4) the reduction rate for pass 1 is higher than in pass3. This follows the guidelines, that we can have more reduction in the early passes without becoming high cross-section spreading. We use the high potential of pass 1 and 2.
Secondary the total reduction is constant. For cross-section 3 and 4 it is fixed to 74.4 % of total reduction. This cannot be changed by modifying the reduction rates with the calibration plan editor.
Also notice, that the reduction behind the oval is smaller than the reduction in oval itself.

VeraCAD-Project with 4 passes Initial commit



Reduction rates after automatic initialisation.



Reduction rates after use of “Reduction Helper”