# *Design*

## of Aluminium Profiles

# *Aluminium Alloys*

***Pure aluminium is soft and easy to shape. For certain purposes these properties are desirable but in most cases the strength of pure aluminium is not high enough. As a result, a large number of aluminium alloys have been developed. The most important alloying elements are silicon (Si), magnesium (Mg), manganese (Mn) and zinc (Zn).***

## Increasing the Strength of Aluminium

The aluminium alloys used in the manufacturing of profiles can be divided into two groups: hardening and non-hardening alloys.

The strength of the non-hardening alloys can be increased by cold working, whereas the strengthening of hardening alloys is mainly carried out by heat treatment. Generally, it is not possible to cold work extruded profiles, among other things, because of the profile shape. Therefore, a heat treatment method called precipitation hardening is widely used to improve the strength properties. This hardening method comprises two separate phases:

1. Solution heat treating and quenching
2. Precipitation hardening (artificial aging)

Aging takes place already at room temperature (natural aging) but generally precipitation hardening is carried out at higher temperatures (artificial aging).

The tempers of extruded profiles are allocated with the following designations:

F = Hot worked

T4 = Solution heat treated and naturally aged

T5 = Cooled from an elevated temperature shaping process and then artificially aged

T6 = Solution heat treated and then artificially aged

T76 = Solution heat treated and then overaged (to ensure good corrosion resistance)

The electrical conductivity, the thermal conductivity and the corrosion resistance of non-alloyed aluminium are generally better than those of alloyed aluminium. Therefore, pure aluminium is widely used for electrotechnical purposes.

The most common alloying element of non-hardening aluminium is magnesium. The AlMg-alloys have good corrosion resistance against chlorides and weak alkalis. The strength increases with increasing magnesium quantity but the formability decreases correspondingly. AlMg-alloys are frequently used in sheets but infrequently in profiles, because it is not possible to use cold working.

| | | Alloy designation<br>SFS-EN 755-2 | Aluminium alloy (hardening) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AW-6060<br>[Al MgSi] | | | AW-6063<br>[Al Mg0,7Si | AW-6063A[3]) [Al Mg0,7Si (A)] | AW-6005A<br>[Al SiMg (A)] | AW-6082<br>[Al Si1 MgMn] | | AW-6101<br>[EAl MgSi] | AW-7108<br>[Al Zn5Mg1Zr] |
| | | Nominal composition/ (alloying elements) % EN 573) | Mg 0,5<br>Si 0,5 | | | Mg 0,7<br>Si 0,4 | Mg 0,7<br>Si 0,4 | Si 0,7<br>Mg 0,6<br>Mn 0,3 | Si 1,0<br>Mg 0,8<br>Mn 0,5 | | Mg 0,5<br>Si 0,4 | Zn 5,3<br>Mg 1<br>Zr 0,2 |
| | | Temper 1)<br>SFS-EN 515 | T4 | T5 | T6 | T6 | T6 | T6 | T5 | T6 | T6 | T6 |
| Strength requirements | Mechanical properties | $R_m$ min<br>mpa 2) | 120 | 160 | 190 | 215 | 230 | 255 | 270 | 290 | 200 | 350 |
| Strength requirements | Mechanical properties | $Rp_{0,2}$ min<br>Mpa 2) | 60 | 120 | 150 | 170 | 190 | 215 | 230 | 260 | 170 | 290 |
| Strength requirements | Mechanical properties | Elongation at break A % min 2) | 18 | 12 | 10 | 10 | 10 | 8 | 8 | 8 | 10 | 10 |
| | Mechanical properties | Hardness HB (approximately) | 40 | 50 | 60 | 70 | 75 | 85 | 80 | 95 | 70 | 110 |
| | Mechanical properties | Modulus of elasticity MPa | 70 000 | | | 70 000 | 70 000 | 70 000 | 70 000 | | 70 000 | 71 000 |
| | Physical properties | Density kg/dm³ | 2,7 | | | 2,7 | 2,7 | 2,7 | 2,7 | | 2,7 | 2,77 |
| | Physical properties | Coefficient of heat expansion 2...100 °C, $10^{-6}$/°K | 23 | | | 23 | 23 | 23 | 23 | | 23 | 24 |
| | Physical properties | Electrical conductivity 20 ° IACS % | | | | | | | | | 30 | |
| | Physical properties | Thermal conductivity 20 °c, W/m °K | 220 | | | 220 | 210 | 210 | 190 | | 220 | 140 |

1)
F = Hot worked
T4 = Solution heat treated and naturally aged
T5 = Cooled from an elevated temperature shaping process and then artificially aged
T6 = Solution heat treated and then artificially aged

2)
The values relate to the most common profile shapes and wall thicknesses.

3)
The composition of the alloying elements differs slightly from the official standard.

## Alloy Alternatives

In the 6000-series the most important hardening alloys are the aluminium-magnesium-silicon –alloys **AW-6060** and **AW-6063**. Due to good strength properties after heat treatment, good corrosion resistance and inexpensiveness, these alloys are by far the most popular among extruded profiles. Moreover, they can be easily anodised, which is very important in architectonic use, for instance in façade structures, doors, windows etc.

These alloys can be used for extruding complex profiles with a demanding surface quality. In the T6 temper the 0,2-limit requirement of the alloy AW-6063 is 170 MPa.

Difficult profiles shapes, thick walls, variations in wall thickness and high surface quality demands favour the T5 temper. This means that the 0,2-limit requirement drops to the value of 120 MPa. If higher strength values are demanded, for instance the 0,2-limit requirement of 170 MPa for the T6 temper, this shall for each profile be subject to agreement between purchaser and supplier. In this case for instance the alloy variant AW-6063A can be used.

The alloys **AW-6082** and **AW-6005A** belong to the same group. They have better strength properties than the alloy AW-6063. For the T6 temper the minimum 0,2-limit requirement of the alloy AW-6082 is 260 MPa and 215 MPa of the alloy AW-6005A. These alloys are of the utmost suitability for different construction purposes, and for primary structures, for instance antenna masts, bridge structures etc, too.

The alloy **AW-7108** of the **7000-series** has been especially developed for welded primary structures. When this alloy is used the strength of the welded seam is only slightly lower than the strength of the base material. The alloys having the highest strengths in this group are used for instance in the aviation industry, where the strength/weight ratio is required to be at its highest, and increasingly for other transport equipment, too, such as railway trucks, truck bodies and other transport vehicles. For the T6 temper the minimum value of the 0,2-limit of the alloy AW-7108 is 290 MPa, and for the T76 temper 260 MPa.

Mn

# *Design of Aluminium Profiles*

***A significant advantage of the extrusion method is that the die costs are low. This is a result of the fact that the hot working temperature of aluminium is relatively low, approximately 500 °C. At this temperature the heat resistant properties of the tool steels are adequate. Consequently, designing of profiles even for a rather small production run is often profitable. Furthermore, the economic efficiency is supported by very careful planning.***

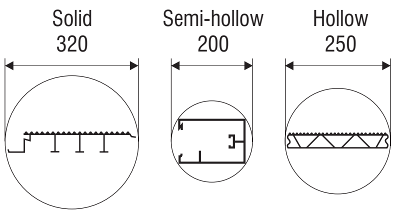
Zn

A profile solution is optimal when a completed structural part, or even a completed product, is generated from the profile by only cutting it, without any other machining.
By no means is this always possible, but with good planning longitudinal machining can be minimised or totally avoided. Transverse machining can be decreased, too, at the designing stage, especially by planning the joins very carefully.

An important phase in the designing of special profiles is to go through all possible applications of use and all details needed. They will not affect the price of the die, but taking them into consideration right at the start may save later costs for modifying the die, or even for a totally new die.

### Extruded Profile Categories

On the basis of the shape of the cross-section of the extruded profiles they can be divided into two or three categories.




The shape is called solid when there is no closed void inside the profile and the profile can also otherwise be produced by using a simple matrix die. Being technically simpler a die like this is more affordable than other types of dies, and often the production values of the profile are better, too, which has a favourable effect on the price of the profile.

The hollow profile, in turn, has at least one closed void, which is made by using a more complicated tool technology. In this case, in front of the matrix part, which forms the external appearance, there is a separate bridge part, with a mandrel attached to it, giving the void its form. In profiles produced with this technique, the walls around the void have longitudinal seams welded in the production. As a result, for example the pressure endurance of the profile is not guaranteed to be very high.

A profile is semi-hollow when there is no closed void inside it, but instead, for instance, it has an open shape, which is so deep that it cannot be made using a simple matrix die. Therefore, a die technique must be used which is of the same type as is used for the hollow profiles. The open shape is achieved using a mandrel attached to the bridge part, as in the method for hollow profiles.

At the gap the mandrel and the matrix are connected to each other. At their joining there might appear some burr in the profile. Another alternative is to arrange, in front of the tongue in the matrix, a fixed attachment made of the same material as the matrix. This latter type is often used in tools for producing cooling profiles with a comb structure. The semi-hollow profile is the least recommended alternative of the types mentioned above. A calculation formula, which facilitates the definition can be found on the next spread.

### Freedom of Choice...

There are only a few restrictions in the designing of profiles. Despite the fact that very narrow and deep pockets cannot be produced by extrusion, the same functional outcome can be achieved with the right design. Conventional profile technology comprises different screw ports, which work without drilling and thread cutting. They can be transverse directed, too.

Si

Si

Zn

Likewise, the heads of transverse screws can be mortised to the surface level with an adequately designed groove and, correspondingly, nuts can be prevented from turning when tightening the bolt, either by using suitable flanges or by placing the nut in an adequately dimensioned groove. Purposely designed hinge functions of the profile, as well as different snap-fit joints, which can be opened or permanently locked, are commonly used, as well as grooves used for attaching rubber or brush gaskets.
With regard to the design of the external appearance, too, extrusion technology is affordable. Today's high quality products are not only functional but the design has become an important element, too. In this respect the method is more adaptable than limiting.

Well planned bridging joins make it easy to use several profiles for assembling profile entities, which means that size limitations of individual profiles are not necessarily an obstacle to producing "grand profiles". Often it is economical to divide a product into several profiles because the tool costs all together can be more affordable than the cost of one single tool for a large profile, and regardless of the joins, the weight of the whole structure can be lower due to the thinner walls of the smaller profiles.

## ...but There Are Also Limitations

The largest size of the profiles we deliver is limited, not only by the structural dimensions of the extrusion press, but also by the type of profile. The size is notified as the diameter of the circumscribing circle.
The maximum diameter of solid profiles is 320 mm, of hollow profiles 250 mm and of semi-hollow profiles 200 mm. Depending on the shape and the dimensions, the hollow and the semi-hollow profiles may occasionally be somewhat bigger.

The weight of the profiles is limited, too. Our upper limit is 35 kg/m length, and for the heavy profiles the delivery length is limited by the 140 kg net weight of the initial billet. In other cases the maximum length of profiles with no surface treatment is 14 m, of painted profiles 8 m and of anodised profiles 7 m. The lowest weight per meter is 100 g/m length, although it can be slightly below in some cases. The thinnest practical wall thickness depends both on the alloy and the type of the profile.

The thicknesses in the graphs on the next page are minimum thicknesses for basic profile shapes of normal degree of difficulty.
In certain details it is possible to go somewhat below these dimensions. In cases of particular difficulty the wall thicknesses must be separately considered. A uniform thickness is recommendable with regard to production conisderations.

On the other hand, the extrusion technique allows material to be placed where it is most advantageous regarding the strength. If the ratio 6:1 between the biggest and the smallest wall thickness is exceeded, the risk of problems grows rapidly. It is recommendable to keep the ratio below 4:1, but even then special solutions are needed for the tools.

Part of the limitations is the tolerances on the dimensions and the form, which, compared to the machining tolerances might appear loose. However, we are talking about a property of a hot working process, and it is not possible to affect the magnitudes of the tolerances.
In fact, a good profile structure must be designed so that it works with normal profile tolerances.

## Experience

Due to the more than 23 000 profiles we have produced so far, our planning department has gained considerable experience, which is at your disposal. We can assist you, not only in designing profiles and taking into account their desired functions, but also in choosing the most appropriate alloy, temper and class of surface quality. In addition, our sales department can make an approximate cost estimate at an early stage of planning.

Consequently, it is advantageous that our planning department takes part in the cooperation at the earliest possible stage and gets acquainted with the needs of the customer.
At the planning stage electronic means of communication ensure an utmost smooth cooperation between the customer and our own planning staff. We employ CAD on our planning and we can handle dwg- and dxf-formats, too. We consider planning to be a very important part of the cooperation with our customers. By honouring secrecy obligations we can ensure that information which is important for our customer is kept secret.



Mg

## Surface Treatment Standards

***Anodising***
- layer thickness: according to SFS-EN ISO 2360
- sealing: SFS-EN ISO 12373-1
- colour: visual control by comparing to model

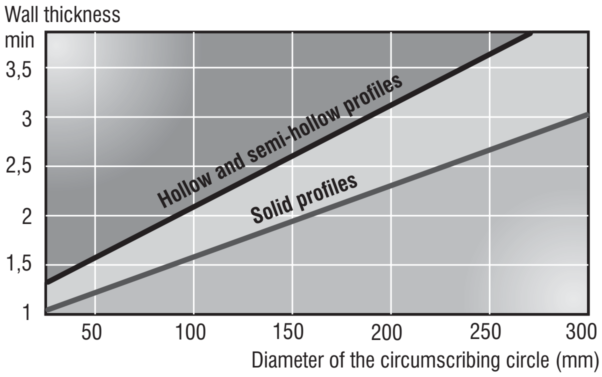
***Painting***
- layer thickness: according to SFS-EN ISO 2360
- adhesion: SFS-EN ISO 2409 (with random tests)
- brightness: SFS 3632
- colour difference: CIELAB max ΔE 1,0 (ΔE is a value that describes the total colour difference between a standard and a batch)
- appearance: visual control.

## Definition of Semi-Hollow Profiles

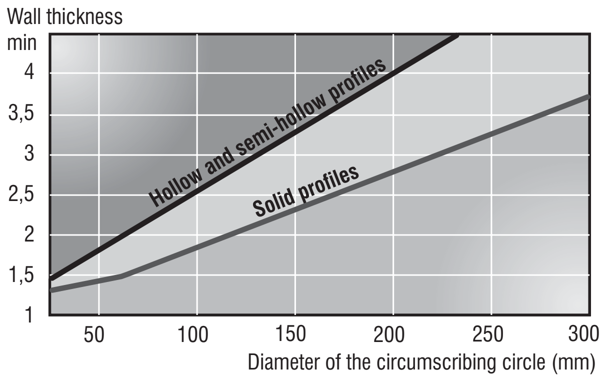
| Gap width in mm | | Ratio $A:b^2$ |
|---|---|---|
| over | max | |
| 4 | 10 | 3,5 |
| 10 | 18 | 4,5 |
| 18 | 30 | 4 |
| 30 | 50 | 3,5 |
| 50 | 80 | 3 |
| 80 | 120 | 2 |
| 120 | - | 1,5 |


## AW-6060 AW-6063

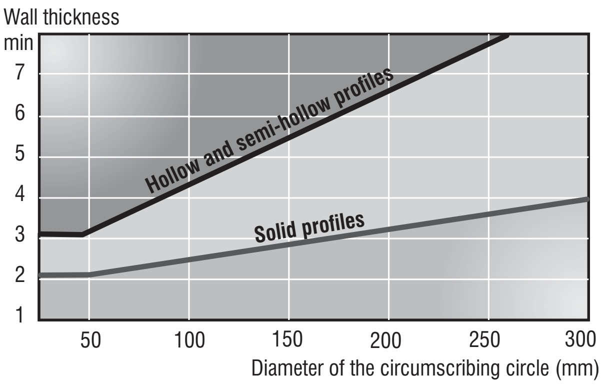
## Selection Graphs for Wall Thickness




## AW-6082




## AW-7108

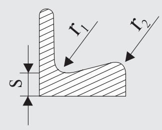



## Corner and Fillet Radii

**For manufacturing technique and tool technique related reasons the so called sharp corners and fillets of profiles are always slightly rounded. The allowable corner and fillet radii shall be specified in the tables below.**

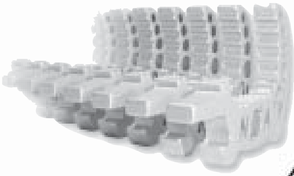
| Wall thickness in mm | | Sharp corner and fillet radii |
|---|---|---|
| over | max | |
| - | 3 | 0,5 |
| 3 | 6 | 0,6 |
| 5 | 10 | 0,8 |
| 10 | 18 | 1,0 |
| 18 | 30 | 1,2 |
| 30 | 50 | 1,6 |

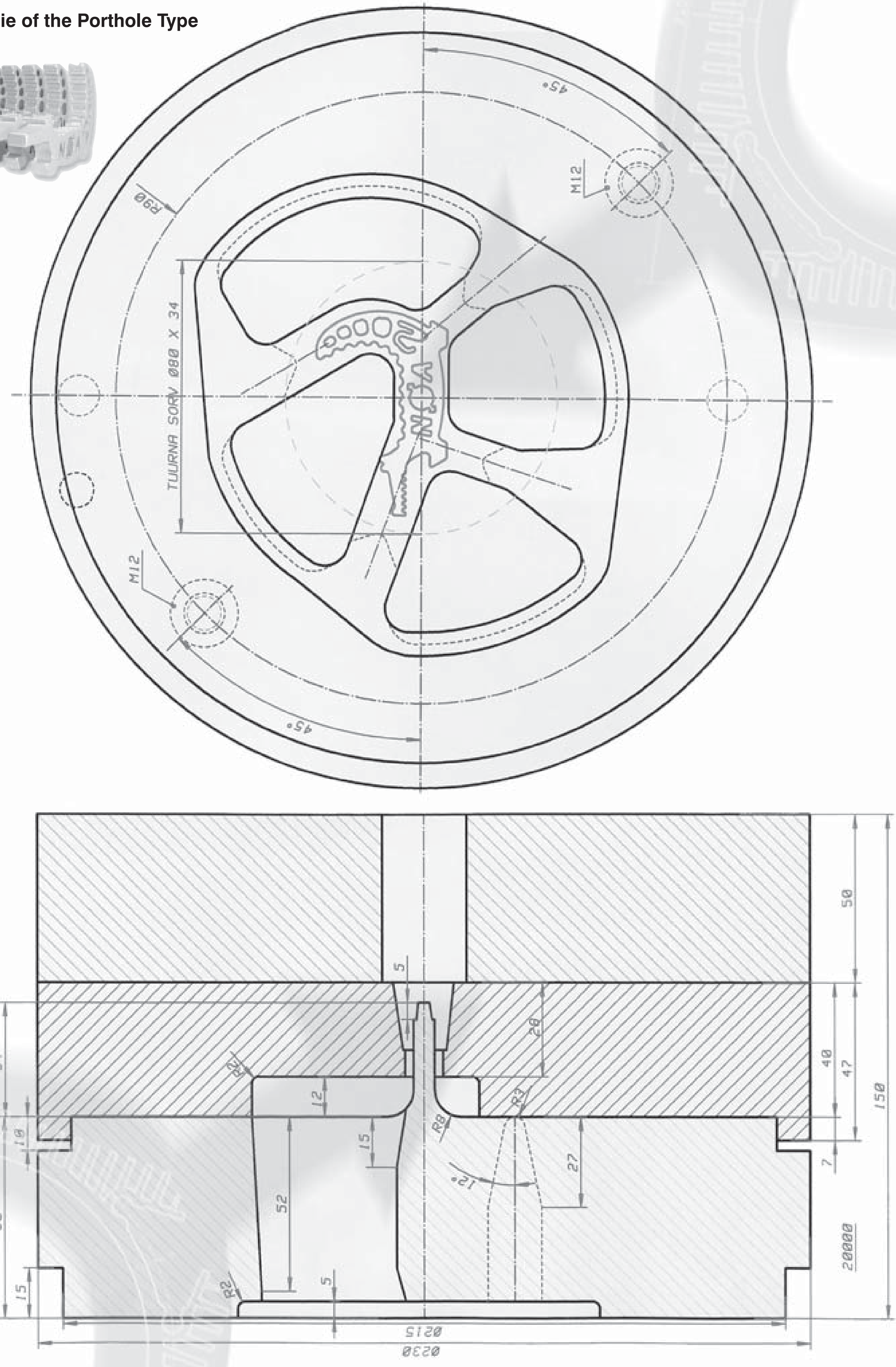
**If so called sharp corners or fillets are not needed for structural reasons, it is recommendable to use corner and fillet radii according to the following table.**




| Wall thickness in mm | | Recommended corner and fillet radii | |
|---|---|---|---|
| over | max | $r_1$ | $r_2$ |
| - | 2 | 2 | 1 |
| 2 | 4 | 2,5 | 1,6 |
| 4 | 6 | 4 | 2 |
| 6 | 10 | 6 | 3 |
| 10 | 20 | 10 | 5 |
| 20 | 35 | 16 | 10 |
| 35 | 50 | 20 | 16 |

**Die of the Porthole Type**





# Tolerances on Dimensions and Form

***We use the tolerances on dimensions and form according to the standard SFS-EN 755-9.***

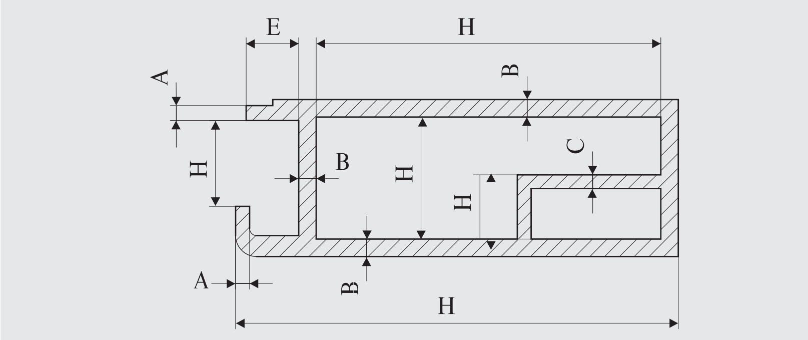
***If agreed, we can apply the standard SFS-EN 12020-2 for profiles which demand greater accuracy.***

| | |
|---|---|
| Group I | EN AW-1050A, EN AW-1070A, EN AW-1200, EN AW-1350,<br>EN AW-3003, EN AW-3103<br>EN AW5005, EN AW-5005A<br>EN AW-6101A, EN AW-6101B, EN AW-6005, EN AW-6005A, EN AW-6106<br>EN AW-6008, EN AW-6060, EN AW-6063, EN AW-6063A, EN AW-6463 |
| Group II | EN AW-2007, EN AW-2011, EN AW-2011A, EN AW-2014, EN AW-2014A<br>EN AW-2017A, EN AW-2024, EN AW-2030<br>EN AW-5019[a], EN AW-5051A, EN AW-5251, EN AW-5052, EN AW-5154A<br>EN AW-5454, EN AW-5754, EN AW-5082, EN AW-5086<br>EN AW-6012, EN AW-6018, EN AW6531, EN AW-6061<br>EN AW-6261, EN AW-6262, EN AW-6081, EN AW-6082<br>EN AW-7003, EN AW-7005, EN AW-7020, EN AW-7022, EN AW-7049A<br>EN AW-7075 |

[a] EN AW-5019 is the new designation for EN AW-5056A.

### Tolerances on Dimensions

A: Wall thicknesses except those enclosing the hollow spaces in hollow profiles.
B: Wall thickness enclosing the hollow spaces in hollow profiles except those between two hollow spaces.
C: Wall thicknesses between two hollow spaces in hollow profiles.
E: The length of the shorter leg of profiles with open ends.
H: All dimensions except wall thickness.




*Alloy Group I*

| Dimension H | | The tolerances on H for the circumscribing circles CD[a b] Dimensions in mm | | | |
|---|---|---|---|---|---|
| over | max | CD≤100 | 100<CD ≤200 | 200<CD ≤300 | 300<CD ≤500 |
| — | 10 | ±0,25 | ±0,30 | ±0,35 | ±0,40 |
| 10 | 25 | ±0,30 | ±0,40 | ±0,50 | ±0,60 |
| 25 | 50 | ±0,50 | ±0,60 | ±0,80 | ±0,90 |
| 50 | 100 | ±0,70 | ±0,90 | ±1,1 | ±1,3 |
| 100 | 150 | — | ±1,1 | ±1,3 | ±1,5 |
| 150 | 200 | — | ±1,3 | ±1,5 | ±1,8 |
| 200 | 300 | — | — | ±1,7 | ±2,1 |
| 300 | 450 | — | — | — | ±2,8 |

For profiles with open ends (see fig.), the tolerances specified in the table on the next page shall be added to the tolerance on the dimension H across open ended legs.

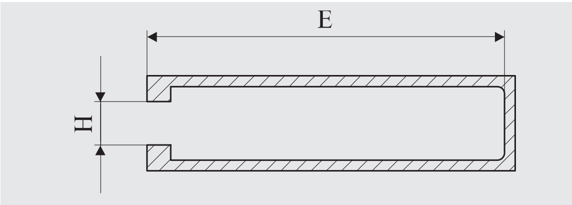
*Alloy Group II*

| Dimension H | | The tolerances on H for the circumscribing circles CD[a b] Dimensions in mm | | | |
|---|---|---|---|---|---|
| over | max | CD≤100 | 100<CD ≤200 | 200<CD ≤300 | 300<CD ≤500 |
| — | 10 | ±0,40 | ±0,50 | ±0,55 | ±0,60 |
| 10 | 25 | ±0,50 | ±0,70 | ±0,80 | ±0,90 |
| 25 | 50 | ±0,80 | ±0,90 | ±1,0 | ±1,2 |
| 50 | 100 | ±1,0 | ±1,2 | ±1,3 | ±1,6 |
| 100 | 150 | —- | ±1,5 | ±1,7 | ±1,8 |
| 150 | 200 | —- | ±1,9 | ±2,2 | ±2,4 |
| 200 | 300 | —- | —- | ±2,5 | ±2,8 |
| 300 | 450 | —- | —- | —- | ±3,5 |

For profiles with open ends (see fig.), the tolerances specified in the table on the next page shall be added to the tolerance on the dimension H across open ended legs.

***Example***

Dimension H 12 mm
Dimension E 100 mm
Alloy group I
Circumscribing circle CD 100 to 200 mm.
The tolerance on H according to Table 2 is ±0,40 mm; plus the additional tolerance according to the table which is ±0,60 mm; total tolerance on H is then ±1,0 mm.




| *Alloy groups I and II* | | |
|---|---|---|
| *Dimension E* | | To the open end gap dimension H (see tables above) is added the tolerances in this table. |
| *over* | *max* | |
| — | 20 | — |
| 20 | 30 | ±0,15 |
| 30 | 40 | ±0,25 |
| 40 | 60 | ±0,40 |
| 60 | 80 | ±0,50 |
| 80 | 100 | ±0,60 |
| 100 | 125 | ±0,80 |
| 125 | 150 | ±1,0 |
| 150 | 180 | ±1,2 |
| 180 | 210 | ±1,4 |
| 210 | 250 | ±1,6 |
| 250 | — | ±1,8 |

## Tolerances on Wall Thickness of the Profiles

| *Alloy group I* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nominal wall thickness A, B or C* | | *Tolerances on wall thicknesses* | | | | | | | | *Dimensions in mm* |
| | | *Wall thickness A circumscribing circle* | | | *Wall thickness B[a] circumscribing circle* | | | *Wall thickness C circumscribing circle* | | |
| *over* | *max* | *CD≤100* | *100<CD 300* | *300<CD ≤500* | *CD≤100* | *100<CD ≤300* | *300<CD ≤500* | *CD≤100* | *100<CD ≤300* | *300<CD ≤500* |
| — | 1,5 | ±0,15 | ±0,20 | ±0,25 | ±0,20 | ±0,30 | — | ±0,25 | ±0,35 | — |
| 1,5 | 3 | ±0,15 | ±0,25 | ±0,35 | ±0,25 | ±0,40 | ±0,60 | ±0,30 | ±0,50 | ±0,75 |
| 3 | 6 | ±0,20 | ±0,30 | ±0,40 | ±0,40 | ±0,60 | ±0,80 | ±0,50 | ±0,75 | ±1,0 |
| 6 | 10 | ±0,25 | ±0,35 | ±0,45 | ±0,60 | ±0,80 | ±1,0 | ±0,75 | ±1,0 | ±1,2 |
| 10 | 15 | ±0,30 | ±0,40 | ±0,50 | ±0,80 | ±1,0 | ±1,2 | ±1,0 | ±1,2 | ±1,5 |
| 15 | 20 | ±0,35 | ±0,45 | ±0,55 | ±1,2 | ±1,5 | ±1,7 | ±1,5 | ±1,9 | ±2,0 |
| 20 | 30 | ±0,40 | ±0,50 | ±0,60 | ±1,5 | ±1,8 | ±2,0 | ±1,9 | ±2,2 | ±2,5 |
| 30 | 40 | ±0,45 | ±0,60 | ±0,70 | — | ±2,0 | ±2,2 | — | ±2,5 | ±2,7 |
| 40 | 50 | — | ±0,70 | ±0,80 | — | — | — | — | — | — |

| *Alloy group II* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nominal wall thickness A, B or C* | | *Tolerances on wall thicknesses* | | | | | | | | *Dimensions in mm* |
| | | *Wall thickness A circumscribing circle* | | | *Wall thickness B[a] circumscribing circle* | | | *Wall thickness C circumscribing circle* | | |
| *over* | *max* | *CD≤100* | *100<CD 300* | *300<CD ≤500* | *CD≤100* | *100<CD ≤300* | *300<CD ≤500* | *CD≤100* | *100<CD ≤300* | *300<CD ≤500* |
| — | 1,5 | ±0,20 | ±0,25 | ±0,35 | ±0,30 | ±0,40 | — | ±0,35 | ±0,50 | — |
| 1,5 | 3 | ±0,25 | ±0,30 | ±0,45 | ±0,35 | ±0,50 | ±0,70 | ±0,45 | ±0,65 | ±0,90 |
| 3 | 6 | ±0,30 | ±0,35 | ±0,60 | ±0,55 | ±0,70 | ±0,90 | ±0,60 | ±0,90 | ±1,2 |
| 6 | 10 | ±0,35 | ±0,45 | ±0,65 | ±0,75 | ±1,0 | ±1,2 | ±1,0 | ±1,3 | ±1,5 |
| 10 | 15 | ±0,40 | ±0,50 | ±0,70 | ±1,0 | ±1,3 | ±1,5 | ±1,3 | ±1,7 | ±1,9 |
| 15 | 20 | ±0,45 | ±0,55 | ±0,75 | ±1,5 | ±1,8 | ±2,0 | ±1,9 | ±1,2 | ±2,5 |
| 20 | 30 | ±0,50 | ±0,60 | ±0,80 | ±1,8 | ±2,2 | ±2,5 | ±2,2 | ±2,7 | ±3,1 |
| 30 | 40 | ±0,60 | ±0,70 | ±0,90 | — | ±2,5 | ±3,0 | — | — | — |
| 40 | 50 | — | ±0,80 | ±1,0 | — | — | — | — | — | — |

## Length

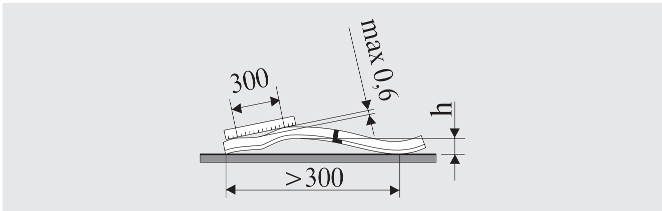
| Length | | | | | Dimensions in mm |
|---|---|---|---|---|---|
| Circumscribing circle diameter CD | | Tolerances on fixed length L | | | |
| over | max | L ≤ 2 000 | 2 000< L ≤ 5 000 | 5 000< L ≤ 10 000 | 10 000< L ≤ 15 000 |
| — | 100 | +5<br>0 | +7<br>0 | +10<br>0 | +16<br>0 |
| 100 | 200 | +7<br>0 | +9<br>0 | +12<br>0 | +18<br>0 |
| 200 | 450 | +8<br>0 | +11<br>0 | +14<br>0 | +20<br>0 |
| 450 | 800 | + 9<br>0 | +14<br>0 | +16<br>0 | +22<br>0 |

## Tolerances on Form

### *Straightness*

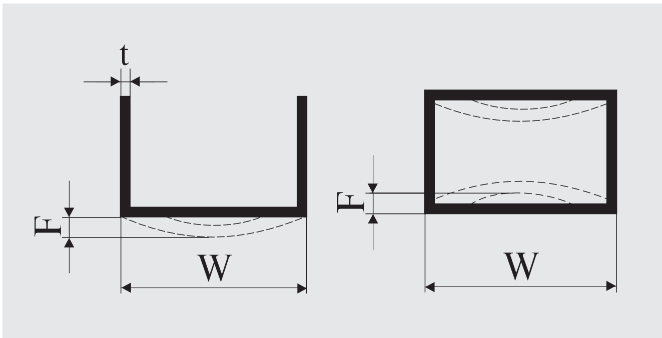
Measurement of deviation from straightness.

The straightness tolerance *h* shall not exceed 1,5 mm/m length. Local deviations from straightness shall not exceed 0,6 mm/300 mm length.




### *Convexity and Concavity*

Measurement of the convexity and the concavity.



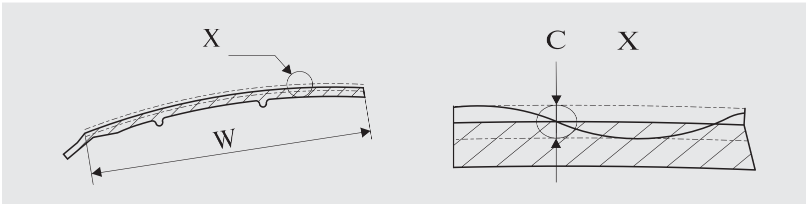

| Convexity and concavity tolerances | | | | Dimensions in mm |
|---|---|---|---|---|
| Width W | | Maximum allowable deviation F | | |
| | | Hollow profiles [a] | | Solid profiles |
| over | max | t ≤ 5 | t >5 | |
| — | 30 | ±0,30 | ±0,20 | ±0,20 |
| 30 | 60 | ±0,40 | ±0,30 | ±0,30 |
| 60 | 100 | ±0,60 | ±0,40 | ±0,40 |
| 100 | 150 | ±0,90 | ±0,60 | ±0,60 |
| 150 | 200 | ±1,2 | ±0,80 | ±0,80 |
| 200 | 300 | ±1,8 | ±1,2 | ±1,2 |
| 300 | 400 | ±2,4 | ±1,6 | ±1,6 |

[a] If the profile has varying wall thicknesses in the measurement range, the thinnest wall thickness shall be used.

*Contour Tolerances*

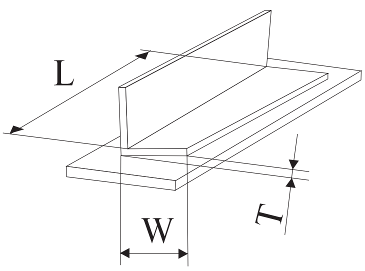
| Contour tolerances | | Dimensions in mm |
|---|---|---|
| Width W | | Contour tolerance = diameter C of the tolerance circle |
| over | max | |
| — | 30 | 0,30 |
| 30 | 60 | 0,50 |
| 60 | 90 | 0,70 |
| 90 | 120 | 1,0 |
| 120 | 150 | 1,2 |
| 150 | 200 | 1,5 |
| 200 | 250 | 2,0 |
| 250 | 300 | 2,5 |
| 300 | 400 | 3,0 |
| [a] If the profile has varying wall thicknesses in the measurement range, the thinnest wall thickness shall be used. | | |

Definition of contour tolerances




## Twist Tolerances

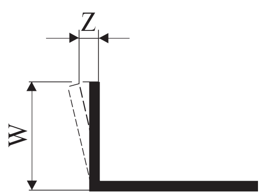
Measurement of twists




| Twist tolerances | | | | Dimensions in mm |
|---|---|---|---|---|
| Width W | | Twist tolerance T for length L | | |
| | | Per 1000 mm of length[a] | On total profile length L | |
| over | max | | max 6 000 | over 6 000 |
| — | 30 | 1,2 | 2,5 | 3,0 |
| 30 | 50 | 1,5 | 3,0 | 4,0 |
| 50 | 100 | 2,0 | 3,5 | 5,0 |
| 100 | 200 | 2,5 | 5,0 | 7,0 |
| 200 | 300 | 2,5 | 6,0 | 8,0 |
| 300 | 450 | 3,0 | 8,0 | 1,5 x *L* (*L* in metres) |
| [a] Twist tolerances for lengths less than 1 000 mm shall be subject to agreement between purchaser and supplier. | | | | |

## Angularity

The maximum allowable deviation in an angle other than a right angle shall be ±1°.




| Angularity tolerances | | Dimensions in mm |
|---|---|---|
| Width W | | Maximum allowable deviation, Z from a right angle |
| over | max | |
| — | 30 | 0,4 |
| 30 | 50 | 0,7 |
| 50 | 80 | 1,0 |
| 80 | 120 | 1,4 |
| 120 | 180 | 2,0 |
| 180 | 240 | 2,6 |
| 240 | 300 | 3,1 |
| 300 | 400 | 3,5 |

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