5 Metal removal rate and chip volume ratio

5.1 Metal removal rate

With regard to the metal removal rate, we have to distinguish between the volume of the removed material Q_w and the space needed for the randomly arranged metal chips Q_{sp}. The volume of the removed material identifies the volume occupied by a chip with cross section $a_p \cdot f$ (depth of cut multiplied with feed) and a defined length per minute.

$$\boxed{Q_w = a_p \cdot f \cdot v_c \cdot 10^3}$$

Q_w	in mm³/min	volume of removed material
a_p	in mm	depth of cut
f	in mm	feed
v_c	in m/min	cutting speed
10^3	mm/m	conversion factor for v_c, from m/min to mm/min

The volume of the randomly arranged metal chips removed Q_{sp} is greater than the real volume of the same amount of removed material Q_w, since, in a reservoir, the chips are not located one next to one another without gaps. Chip volume ratio R defines by what factor the volume of the randomly arranged chips Q_{sp} is greater than the volume of the removed material Q_w.

$$\boxed{Q_{sp} = R \cdot Q_w}$$

Q_{sp}	in mm³/min	volume of randomly arranged chips
Q_w	in mm³/min	volume of removed material
R		chip volume ratio

Consequently, chip volume ratio R results from the ratio:

$$R = \frac{\text{Volume needed for randomly arranged metal chips}}{\text{Material volume of the same amount of metal removal}}$$

The amount of the chip volume ratio R depends on the chip shape.

5.2 Chip shapes

The form of the chips generated during metal cutting depends on:

type and alloy of the workpiece material,
the material's phosphor- and sulphur contents
the cutting conditions (cutting speed, depth of cut, feed, tool cutting-edge angle etc.),
rake angle and the formation of the chip form level.

The chip shapes are assessed according to two criteria.

5.2.1 Transportability

It is no problem to move short, broken chips, such as fragmented spiral chips, in containers.

By contrast, this is impossible for ribbon chips, since they always demand special treatment (breaking in the chip breaker or briquetting) in order to make them ready for transport.

In a plant with automated manufacturing equipment, where many chips occur, these treatment procedures are very expensive. Consequently, as an alternative, we always aim to produce chip forms that can be handled easily.

5.2.2 Danger for the machine operator

Certain chip forms, such as long ribbon chips and entangled chips whose edges are very sharp, endanger the machine operator.

5.3 Chip volume ratios

Figure 5.1 summarises the most significant chip shapes. Each chip form is assigned to a chip volume ratio *R*, which defines by what factor the transport volume needed for the specific chip form exceeds the intrinsic material volume of the chip.

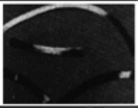
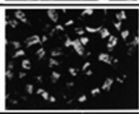
Chip shape		Chip volume ratio R
Ribbon chip		> 100
Entangled chip		> 100
Coil chip		60
Short coil chip		30
Spiral chip		10
Short chip particles		3
R ≤ 3 Easily usable, R = 31-60 Usable with limitations,		R = 4-30 Ok R > 100 Indesirable

Figure 5.1
Chip shapes and chip volume ratios
Chip form representations from [11 and 12]

The appraisal of the chip form involves both criteria (safety of the operator and transportability). According to this approach, ribbon-, entangled- and coil chips are not preferred. The desirable chip forms are short coil chips, spiral chips and pieces of spiral chips.