

Parts produced by milling

Process description

Milling is a machining operation in which a work part is fed past a rotating cylindrical tool with multiple cutting edges (rare case single edge cutting tool called a fly cutter). The axis of rotation of the cutting tool is perpendicular to the direction of feed. The cutting tool in milling is called a milling cutter. The machine used to do this operation is called a milling machine. Milling process produces plane, form, or profile surface geometry. There are two types of milling operation: (a) Peripheral milling and (b) Face milling. Figure M3.4.1 shows the peripheral milling.

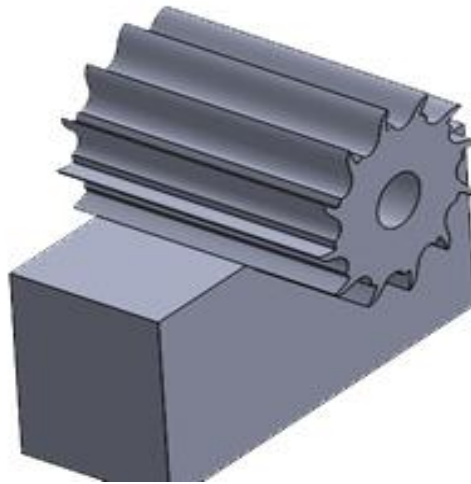


Figure M3.4.1: Peripheral milling

In peripheral milling (also called plain milling), the axis of the tool is parallel to the surface being machined and the operation is performed by the cutting edges on the outside periphery of the cutter.

In the case of face milling the axis of the cutter is perpendicular to the surface of machining. The machining is performed by cutting edges on both the ends and outside periphery of the cutter.

Characteristics and applications of parts produced on milling machines

If large amount of material is required to remove from the stock, then using milling process is an efficient method to produce flat surfaces and slots. Milling-machine

operations are generally more beneficial, when close fittings are required between moving parts or when sealing is involved or when an accurate fit is expected. The degree of precision of parts obtained from milling process are much better than the same parts obtained by other processes such as casting, forging, extrusion.

The parts produce through milling operations are: automobile engine blocks and automobile cylinder heads, open end wrenches and other hand tools, gearboxes, brackets, ribs, fittings, flanges, spars, beams, pumps, printing presses, machine tool components, aircraft parts, etc. One more common application is milling of surface before surface grinding.

Suitable materials for milling

Various materials commonly processed by milling are both ferrous and nonferrous components obtained by the following processes:

- Castings
- Forgings
- Hot and cold rolled or drawn shapes
- Extrusions
- Powder-metal and cold-formed (less common)

High machinability rating materials are common for milling process. In addition, soft materials and those with hardness up to about R_C45 are also can be processed, but at higher cost. Materials having higher hardness require lower cutting speed and reduced feed per tooth.

Design recommendations

If the component can be achieved by other processes like casting, extruding, forging, drawing, then milling should be avoided as it adds to the product cost. Many design recommendations which are applicable to other machining process are also applicable to milling operation. The recommendations like sharp edges at the corners should be avoided, the design should be such that it can be easily clamped, machined surface should be accessible, and design should be as simple as possible, are common with other design rules.

Some specific recommendations for milling process are listed below. By following these recommendations, it is possible to reduce the setup time, result more economical cutters, improved processing, and lower cost.

1. It is recommended to use standard cutter shapes and sizes. Specialized nonstandard cutters are costly and difficult to maintain. (Refer Figure M3.4.2.)

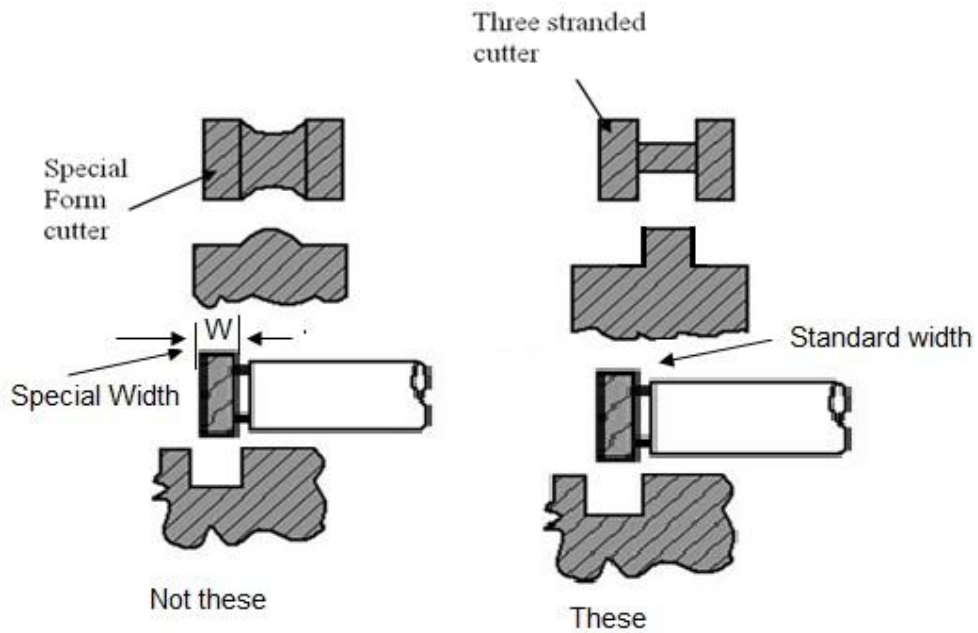


Figure M3.4.2: Use standard cutter shapes and sizes

2. The manufacturer should be given a preference to determine the radius where two milled surfaces intersect or where profile milling is involved. By this standard available or most easily ground cutter scan be used (See Figure M3.4.3.)

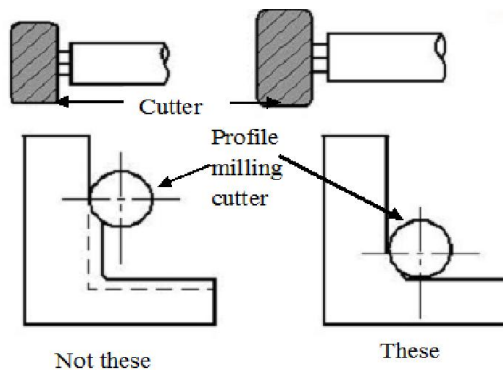


Figure M3.4.3: Product design should permit the use of the radii provided by the cutting tool.

3. To produce small and flat surface, use of spot facing, which is quicker and more economical than face milling is preferred. (Refer Figure M3.4.4)

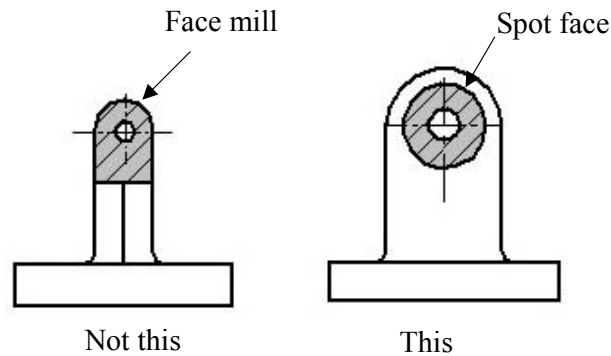


Figure M3.4.4: Spot-facing is quicker and more economical than face milling for small, flat surfaces.

4. If spot-faces or other small milled surfaces are specified for castings, it is recommended to design a low boss for the surface to be machined. This simplifies machining and paint removal and resulting in a less sharp edge.(Refer Figure M3.4.5)

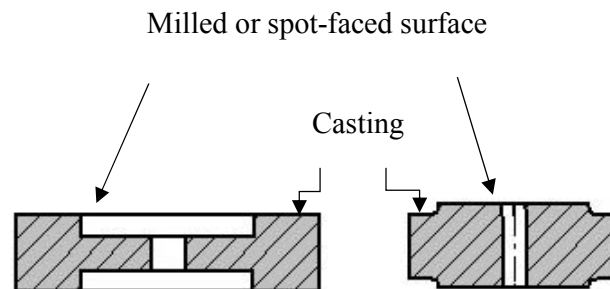


Figure M3.4.5:A low boss simplifies the work of machining a flat surface

5. If outside surfaces intersect and sharp corners are not required then it is recommended to create bevels and chamfers by using face mills. The other alternative is rounding which requires a form-relieved cutter and a more precise setup, both of which are most costly to maintain. (Refer Figure M3.4.6)

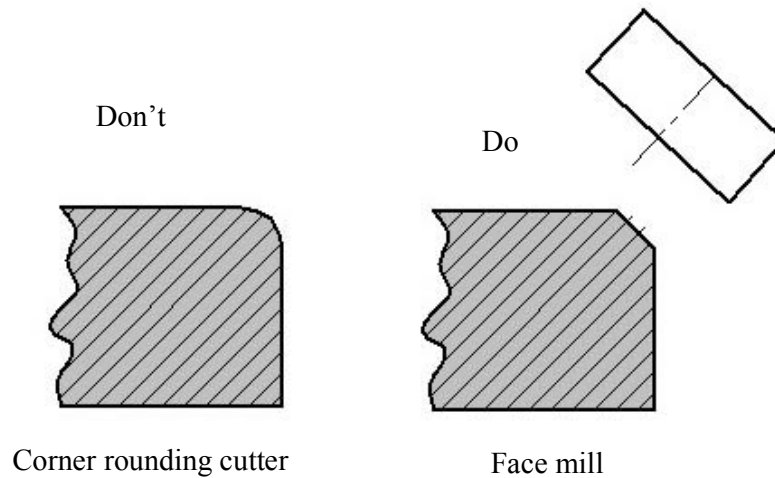


Figure M3.4.6: Allowing a beveled rather than a rounded corner for more economical machining

6. Do not blend the formed surface to an existing milled surface because exact blending is difficult to achieve in case of form-milling or machining rails. (Refer Figure M3.4.7)

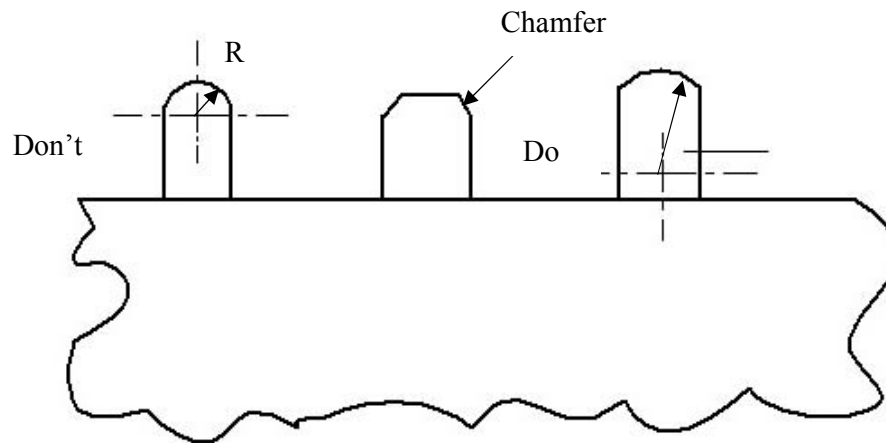


Figure M3.4.7: Avoid to specify a blended radius on machined rails.

7. Keyway should be designed in such a way that standard cutters can produce both sides and ends in one operation. This principle also applies to other slots, saw cuts, and shell and face milling. (See Figure M3.4.8)

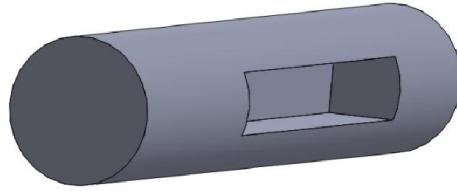


Figure M3.4.8: Use standard cutter to produce both sides and ends of keyways in one operation

8. Clearance should be provided for milling cutters.(Refer Figure M3.4.9)

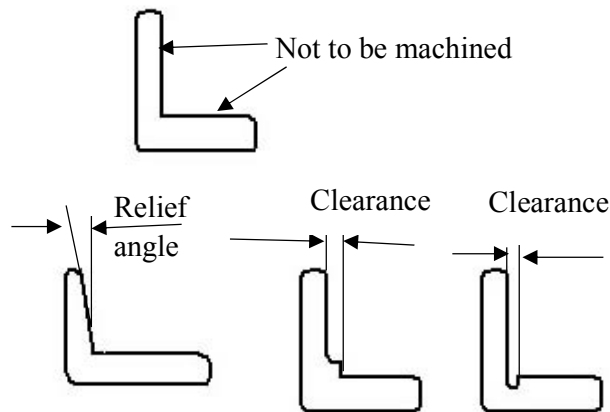
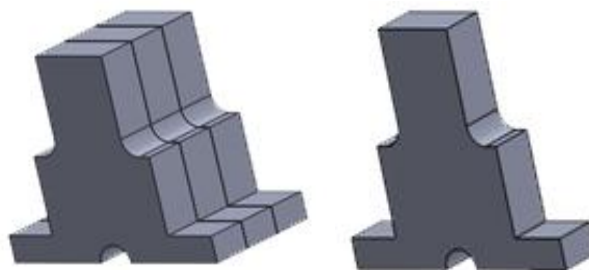


Figure M3.4.9: Provide clearances for the milling cutter.

9. It is recommended to avoid milling at parting lines, flash areas, and weld-ments for higher cutter life.
10. It is preferred to have fewest separate operations for surface-machining processes. Surfaces in the same plane or at least in the same direction and in parallel planes are preferred.
11. Form milling is an economical approach if product design permits stacking or slicing operations.(Refer Figure M3.4.10)



Stacked and milled

Un-stacked

Figure M3.4.10: Designs that permit stacking or “slicing” with form milling

12. It is necessary to provide clearance to allow the use of larger-size cutters in order to permit high material removal rates. Smaller-sized cutters are more prone to vibration, chatter, and deflection of tool and machine components.
13. End-milling slots in mild steel should not be deeper than the diameter of the cutter. (Refer Figure M3.4.11)

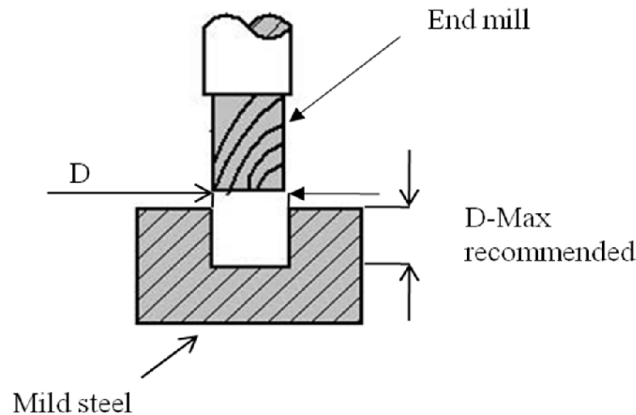


Figure M3.4.11: Recommended end-milled slots in steel

Dimensional factors and tolerances

Table M3.4.1 summarizes the recommended dimensional tolerances for different milling operations. These tolerances are provided for production work with properly maintained machines. The accuracy to tolerance is influenced by condition of the cutter, machine, and work-holding device. In addition, operational disturbances such as tool wear, machine wear, deflection, and vibration and the rigidity and stability of the work piece also play an important role in tolerance-holding capabilities.

Table M3.4.1: Recommended dimensional tolerances for milling operations (*Source: Design for Manufacturability Handbook by James G Bralla, 2nd Ed*)

Operation	Basic dimension, mm					
	To 6.3	To 12.7	To 19	To 25	To 50	To 100
Straddle milling	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5
Slot width	±0.04	±0.04	±0.05	±0.05	±0.05	±0.06
Slot width (end mill)	±0.05	±0.06	±0.06	±0.06		
Face milling	±0.05	±0.05	±0.05	±0.05	±0.05	±0.05
Hollow milling	±1.5	±2.0	±2.50			