RAPID® DIRECT

# CNC Machining Tolerance

CNC machining tolerance refers to the degree of deviation permitted in the dimensions of a machined part. It's essentially a measure of precision that indicates how closely the machined part will match the dimensions specified in the design.

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*Chapter 01*

# GENERAL TOLERANCES FOR LINEAR AND ANGULAR DIMENSIONS

# Linear Dimensions

In CNC machining, linear dimensions refer to the measurable distances between two points or surfaces on a part. They are measured in millimeters or thousandths of an inch and are vital for part accuracy and functionality. They indicate allowable measurement deviations, balancing precision with manufacturing complexity and cost.

**Table 1: General Tolerance for Linear Dimensions (in mm)**

| Tolerance Class Designation (Description) | Nominal Feature Length (mm) Permissible Dimensional Deviation in mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.5~3 | >3~6 | >6~30 | >30~120 | >120~400 | >400~1000 | >1000~3000 | >200~4000 |
| Precision (f) | ±0.05 | ±0.05 | ±0.1 | ±0.15 | ±0.2 | ±0.3 | ±0.5 | / |
| Medium (m) | ±0.1 | ±0.1 | ±0.2 | ±0.3 | ±0.5 | ±0.8 | ±1.2 | ±2 |
| Coarse (c) | ±0.2 | ±0.3 | ±0.5 | ±0.3 | ±1.2 | ±3 | ±3 | ±4 |
| Very Coarse (v) | / | ±0.5 | ±1 | ±1.5 | ±2.5 | ±6 | ±6 | ±8 |

# Fillet Radius And Chamfer Height Dimensions

Fillet Radius and Chamfer Height tolerances in CNC machining dictate the precision of rounded edges and angled transitions. Adhering to these tolerances is crucial for maintaining part strength, ensuring proper fit in assemblies, and achieving desired aesthetics, especially in components with intricate design features.

**Table 2: General Tolerance for Fillet Radius and Chamfer Height Dimensions**

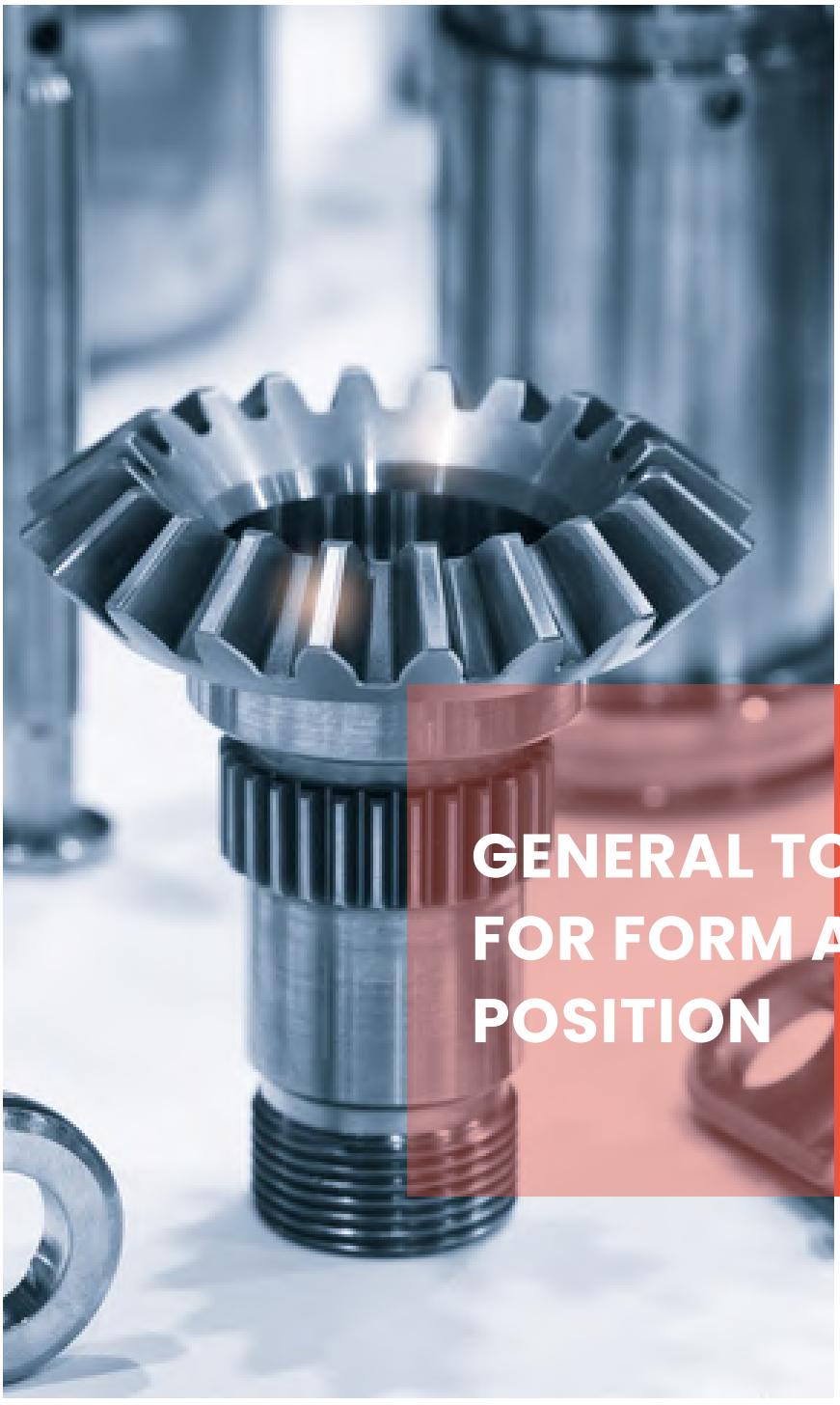
| Tolerance Class Designation (Description) | Nominal Feature Length (mm) Permissible Dimensional Deviation in mm | | | |
|---|---|---|---|---|
| | 0.5~3 | >3~6 | >6~30 | >30 |
| Precision (f) | ±0.05 | ±0.05 | ±0.1 | ±0.15 |
| Medium (m) | ±0.1 | ±0.1 | ±0.2 | ±0.3 |
| Coarse (c) | ±0.2 | ±0.3 | ±0.5 | ±0.3 |
| Very Coarse (v) | / | ±0.5 | ±1 | ±1.5 |

# Angular Dimensions

Angular dimension tolerance in CNC machining refers to the permissible deviation in angles between specified surfaces or features. It is crucial for ensuring the correct assembly and functionality of components, especially in complex designs where precise angular relationships are essential for structural integrity and performance.

**Table 3: General Tolerance for Angular Dimensions**

| Tolerance Class Designation (Description) | Nominal Feature Length (mm)<br>Permissible Deviations in Degrees and Minutes | | | | |
|---|---|---|---|---|---|
| | ~10 | >10~50 | >50~120 | >120~400 | >400 |
| Precision (f) | ±1° | ±30' | ±30' | ±10' | ±5' |
| Medium (m) | | | | | |
| Coarse (c) | ±1°30' | ±1° | ±20' | ±15' | ±10' |
| Very Coarse (v) | ±3° | ±2° | ±1 | ±30' | ±20' |



*Chapter 02*

# GENERAL TOLERANCES FOR FORM AND POSITION

# Straightness And Flatness

Straightness and Flatness tolerances in CNC machining dictate the allowable deviations in a part's linear and surface evenness. Emphasizing these tolerances is crucial for guaranteeing precise component alignment and uniform contact surfaces, which are essential for mechanical functionality and the integrity of assembly operations.

**Table 1: General Tolerance for Straightness and Flatness**

| Tolerance Class Designation (Description) | Ranges of nominal lengths in mm | | | | | |
|---|---|---|---|---|---|---|
| | ~10 | >10~30 | >30~100 | >100-300 | >300-1000 | >1000~3000 |
| H | 0.02 | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 |
| K | 0.05 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 |
| L | 0.1 | 0.2 | 0.4 | 0.8 | 1.2 | 1.6 |

# Perpendicularity

Perpendicularity tolerance in CNC machining specifies the acceptable deviation for a part's angle relative to a 90-degree reference. This tolerance is critical for ensuring components assemble correctly and function as intended, particularly in designs where right angle precision impacts overall mechanical performance and structural stability.

**Table 2: General Tolerance for Perpendicularity**

| Tolerance Class Designation (Description) | Ranges in Nominal Lengths in mm | | | |
|---|---|---|---|---|
| | ~100 | >100-300 | >300-1000 | >1000~3000 |
| H | 0.2 | 0.3 | 0.4 | 0.5 |
| K | 0.4 | 0.6 | 0.8 | 1 |
| L | 0.5 | 1 | 1.5 | 2 |

# Symmetry

Symmetry tolerance in CNC machining defines the permissible deviation from a perfect mirror image across a specified axis. This tolerance is crucial for parts where balanced distribution of mass and uniformity of features are essential, ensuring optimal performance, aesthetic appeal, and consistent functionality in the final assembly.

**Table 3: General Tolerance for Symmetry**

| Tolerance Class Designation (Description) | Ranges in Nominal Lengths in mm | | | |
|---|---|---|---|---|
| | ~100 | >100-300 | >300-1000 | >1000~3000 |
| H | 0.5 | | | |
| K | 0.6 | | 0.8 | 1 |
| L | 0.5 | 1 | 1.5 | 2 |

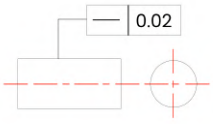
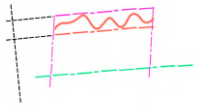
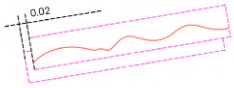
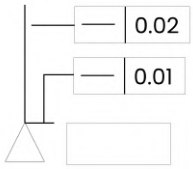
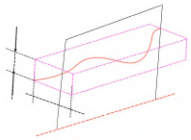
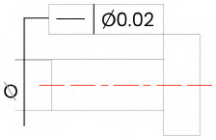
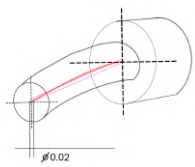
# Runout

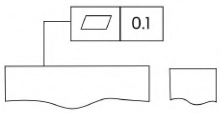
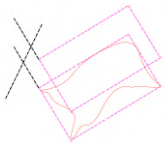
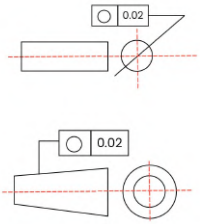
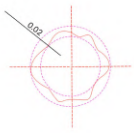
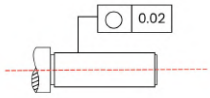
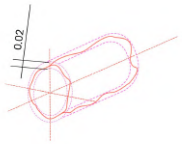
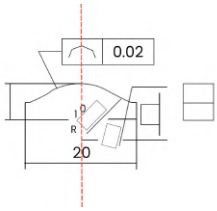
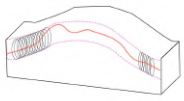
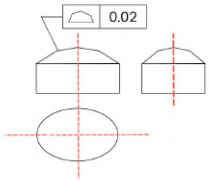
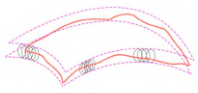
Runout tolerance in CNC machining specifies the allowable deviation from a true concentric rotation of a part around its axis. Maintaining tight runout tolerances is essential for parts that rotate or interact with moving components, ensuring smooth operation, minimal vibration, and prolonged equipment life.

| Table 4: General Tolerance for Runout | |
|---|---|
| **Tolerance Class Designation (Description)** | **Ranges in Nominal Lengths in mm** |
| H | 0.1 |
| K | 0.2 |
| L | 0.5 |

*Chapter 03*

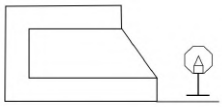
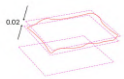
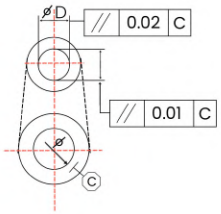
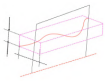
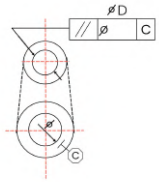
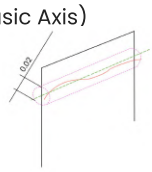
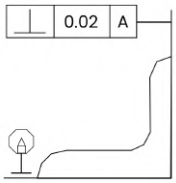
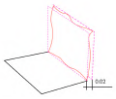
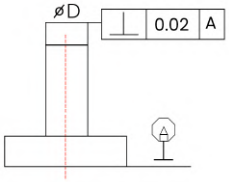
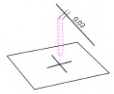
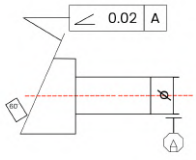
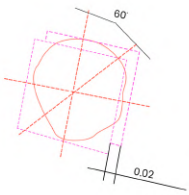
# DESCRIPTION OF SHAPE TOLERANCE TYPES AND EXAMPLES

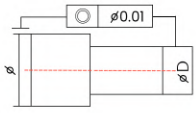
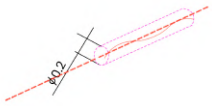
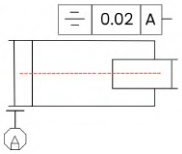
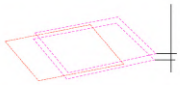
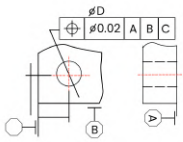
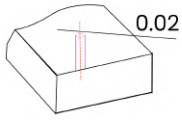
| Item | Tolerance band definition | | Example | Explanation |
|---|---|---|---|---|
| Straightness | Within a given plane | The tolerance band is the area between two parallel lines at a distance of tolerance value t. |  | Any generatrix on the cylindrical surface must lie within an axial plane, between two parallel lines at a distance of 0.02.  |
| | Within a given direction | When a direction is given, the tolerance band is the area between two parallel planes at a distance of tolerance value t |  | The edge line must be within two parallel planes in the direction indicated by the arrow, at a distance of a tolerance value of 0.02.  |
| | | When two mutually perpendicular directions are given, the tolerance band is the area within a quadrangular prism with a side length of t1+2. |  | The edge line must be within a quadrangular prism with a horizontal distance tolerance value of 0.02 and a vertical distance of 0.01.  |
| | | In any direction, the tolerance band is the area of a cylindrical surface with a diameter of tolerance value t. |  | The axis of the cylinder must be within a cylindrical surface with a diameter tolerance value of 0.02.  |

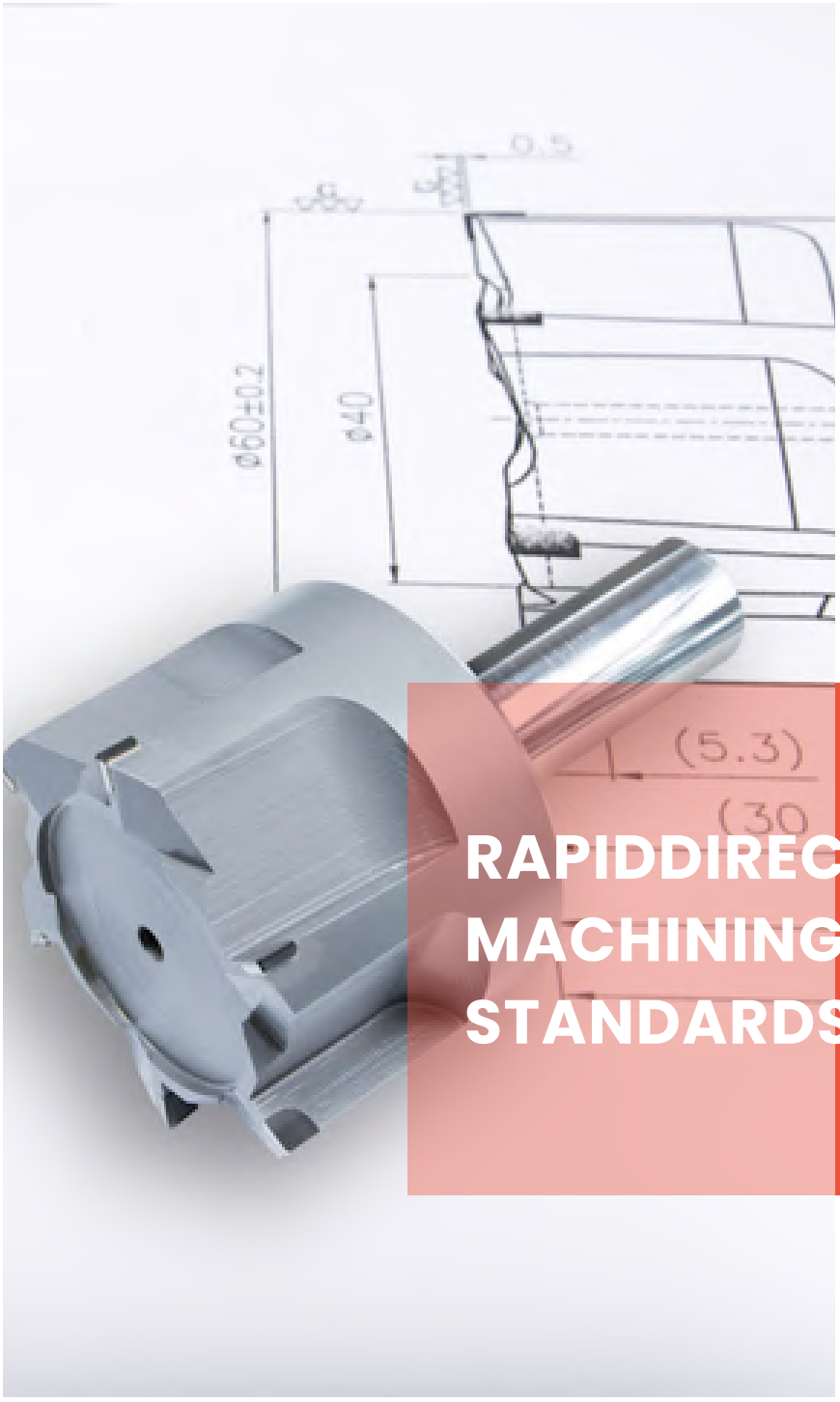
| | | | | |
|---|---|---|---|---|
| Flatness | The tolerance band for flatness is the area between two parallel planes at a distance of tolerance value t. |  | The top surface must be within two parallel planes at a distance of a tolerance value of 0.1. |  |
| Roundness | The tolerance band for roundness is the area between two concentric circles on the same cross-section with a radius difference of tolerance value t. |  | The edge line must be within two parallel planes in the direction indicated by the arrow, at a distance of a tolerance value of 0.02. |  |
| Cylindricity | The tolerance band for roundness is the area between two concentric circles on the same cross-section with a radius difference of tolerance value t. |  | The edge line must be within two parallel planes in the direction indicated by the arrow, at a distance of a tolerance value of 0.02. |  |
| Line Profile | The tolerance band for line profile is the area between two envelope lines that envelop a series of circles with a diameter of tolerance value t, where the center of these circles should lie on the ideal profile. |  | On any cross-section parallel to the standard projection plane, the actual profile must be within the two envelope lines that envelop a series of circles with a diameter tolerance value of 0.02, and the centers of these circles lie on the ideal profile line. |  |
| Surface Profile | The tolerance band for surface profile is the region between two envelope surfaces that envelop a series of spheres with a diameter of tolerance value t, where the centers of these spheres should lie on the ideal profile. |  | The actual profile surface must lie between the two envelope surfaces of a series of spheres, where the diameter of these spheres is a tolerance value of 0.02, and the centers of these spheres are on the ideal profile surface." |  |

*Chapter 04*

# POSITIONAL TOLERANCE EXAMPLE EXPLANATION

| Item | Tolerance band definition | | Example | Explanation |
|---|---|---|---|---|
| Orientation Positional Tolerance | Parallelism | When given in one direction, the tolerance band is the region between two parallel planes that are a distance of tolerance value 't' apart and parallel to a reference plane. |  | Any generatrix on the cylindrical surface must lie within an axial plane, between two parallel lines at a distance of 0.02.  |
| | | When given in two mutually perpendicular directions, the tolerance zone is the region inside a prism with cross-sectional dimensions of tolerance values 't1' and 't2', and is parallel to the reference axis |   | The axis must lie within a prism defined by cross-sectional dimensions with tolerance values of 0.01 and 0.02 and must be parallel to the reference axis C. (Basic Axis)  |
| | | In any given direction, the tolerance zone is the region inside a cylindrical surface with a diameter of tolerance value 't' and parallel to the reference axis. |   | (Basic Axis)  |
| Directional Positional Tolerance | Perpendicularity | The tolerance zone is the region between two parallel planes (or lines) at a distance of tolerance value 't' and perpendicular to the datum plane (or line or axis). |   | The right side surface must be positioned between two parallel planes that are 0.02 apart in terms of tolerance and perpendicular to the datum plane A.  |
| | | The tolerance zone is within a cylindrical surface with a diameter of tolerance value 't' and perpendicular to the datum plane. |   | The axis must lie within a cylindrical surface with a diameter tolerance of 0.02 and be perpendicular to the  |
| | Inclination | The tolerance zone is the region between two parallel planes at a distance of tolerance value 't' and at a theoretically correct angle to the reference axis. |   |   |

| Item | Tolerance band definition | | Example | Explanation |
|---|---|---|---|---|
| Positional Tolerance | Coaxiality | The tolerance zone is within a cylindrical region with a diameter of tolerance value 't', and is coaxial with the datum axis. |  | The axis must be located within a cylindrical surface with a diameter tolerance of 0.01, and be coaxial with the datum axis.<br>(Datum Axis)<br>  |
| | Symmetry | The tolerance zone is between two parallel planes spaced by a tolerance value 't', and is symmetrically arranged relative to the datum median plane. |  | The center plane of the groove must be positioned between two parallel planes that are 0.02 apart in terms of tolerance, and symmetrically arranged relative to the datum median plane.<br>(Datum Median Plane)<br>  |
| | Position | The positional tolerance for a line is within a cylindrical region with a diameter of tolerance value 't', centered on the ideal position of the line. |  | The axis must be located within a cylindrical surface with a diameter tolerance of 0.2, and centered on the ideal position determined by the datums A and B.<br>  |

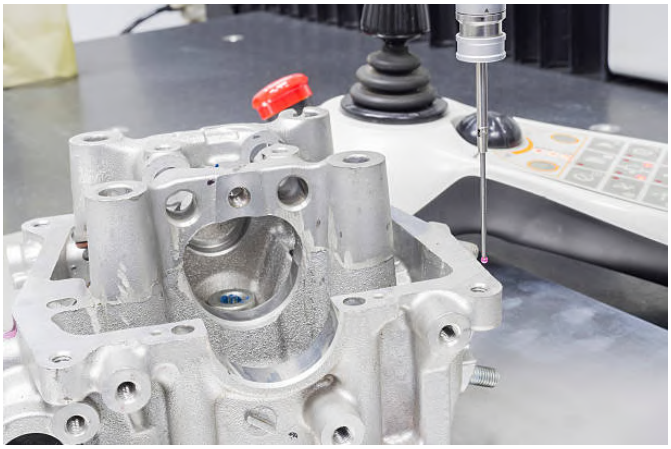



*Chapter 05*

# RAPIDDIRECT CNC MACHINING TOLERANCE STANDARDS

# Tolerance Standard

RapidDirect sets default tolerances for manufacturing processes to ensure precision and quality. For linear and angular dimensions, the standard tolerance level is 'm' for metal materials and 'c' for plastics, unless customers specify otherwise.



When it comes to form and position tolerances, RapidDirect adheres to a 'K' level by default, in the absence of specific customer requirements.

Leveraging our advanced CNC machining capabilities, RapidDirect can accommodate both standard and tighter tolerances. Customers are encouraged to clearly indicate any special tolerance requirements on their technical drawings.

# *Quality Parts Made*
# *Easier, Faster*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