Accuracy and Mold Direction of PTFE Products

1. Introduction

In general, the accuracy of PTFE product is not easy to control because its coefficient of linear expansion is higher than that of metals, and its one of volume transition temperature is around room temperature causes volume changes approximately 1 to 2%. Moreover, thin-walled PTFE products are known to be difficult to machining because not only PTFE is flexible and elastic material, but also residual stress remains after molding sometimes deform due to frictional heat generated during the machining process or due to aging after machining. Such deformation could influence dimensional accuracy.

Regarding processing accuracy, PTFE products are sometimes required the same permissible dimensional tolerance as for a metal material. In such cases, the characteristics of PTFE described above could cause troubles between users and manufacturers. With this background, this report explains the processing accuracy of PTFE.

2. General Permissible Dimensional Tolerance

Table1 shows "General Tolerance for Polytetrafluoroethylene (Machine Cut)" stipulated in JIS K 6884-1971.

This standard stipulates dimensions ranging from 1 mm to 1000 mm for when the material of a PTFE molded product is machined through compression or extrusion molding. The term "general" used in this standard means that the standard can be applied when a blueprint shows no figures or symbols.

When measuring the processing accuracy of PTFE, the following essential characteristics of PTFE should be taken into account:

1. PTFE has low thermal conductivity.
2. PTFE has a high coefficient of linear expansion.
3. PTFE's volume changes markedly (by approximately 1 to 2%) at around 23°C.
4. PTFE is elastic.
5. PTFE sometimes has residual stress.

Table1 General tolerance for polytetrafluoroethylene (machine cut)

Unit: mm

Categories of nominal dimension			Tolerance	
			Grade 1	Grade 2
1	up to	16	±0.1	±0.3
More than 16	up to	40	±0.2	±0.6
More than 40	up to	63	±0.3	±0.8
More than 63	up to	100	±0.4	±1.0
More than 100	up to	160	±0.5	±1.2
More than 160	up to	250	±0.6	±1.4
More than 250	up to	400	±0.7	±1.7
More than 400	up to	630	±1.0	±2.0
More than 630	up to	1000	±1.5	±2.5

From the above, PTFE's dimensional minimum tolerance is approximately ±0.05 mm or half the value stipulated in JIS K 6884 (grade 1), although PTFE's machining accuracy depends on the size and shape.

However, because of PTFE's elasticity, an accurate value could be varied if the end of a measuring device is pushed strongly against a PTFE specimen. For example, a difference of at least 0.1 mm in measured values sometimes occurs depending on how a micrometer is pushed against a PTFE specimen. Users and manufacturers should consider this point.

3. Effects of Annealing Treatment

Usually, free sintering (baking) process is applied to PTFE after compression molding. During sintering, PTFE's internal stress could be decreased compare with molded products with coining process (a process in which a material is sintered in a mold and then cooled under pressure) whose outer layer is quenched. However, annealing* treatment is applied to the material in case high dimensional accuracy is required or the product shape is complex.
Eliminating the internal stress generated during molding process is an effective way to improve dimensional accuracy and to prevent from its change over time.

*Annealing: A procedure in which molded products are slowly cooled at a given temperature to remove internal stress generated by heat or mechanical stress.

4. Surface Roughness

As stipulated in General Tolerance for Polytetrafluoroethylene (Machine Cut), material characteristics should be taken into account when setting a surface-roughness value.
Since resin is affected by heat during machining on the surface and has elasticity, the surface-roughness value could not equal to the machined metal surface.
Generally, a difference in the finish of surface roughness is caused by the machining conditions including rotational and feeding speed and cutting tools (blades).

Table 2: Standard values of surface roughness of PTFE
Figure 1: Calculated average roughness (Ra)
Figure 2: Maximum peak (Rmax)
Figure 3: A machining method for round bars and sleeves
Figure 4: A machining method for sheet (plate material)

Table2　Categories of roughness

New JIS symbol		Former JIS symbol		Applicability standard for machining
Symbol	Arithmetical mean roughness	Symbol	Maximum roughness	
√	12.5 to 25 a	▽	50 to 100 S	Acceptable
√	3.2 to 6.3 a	▽▽	12.5 to 25 S	Acceptable
√	0.4 to 1.6 a	▽▽▽	1.6 to 6.3 S	(Conditionally acceptable, in the case of sheet)
√	0.012 to 0.2 a	▽▽▽▽	0.05 to 0.8 S	Unacceptable

(Unit: μm)

The comparison of the two symbol types (new and former JIS symbols) shown in Table 2 is not strictly precise; it is shown for convenience. Even today, many companies continue to use the former JIS symbols.
The former symbols were introduced approximately 60 years ago, and so are well known. It will take time for the new symbols to become known among peripheral manufacturers. In addition, in the case of functional parts, existing techniques tend to be followed. Therefore, it is important to understand the relationship between the new and former symbols.

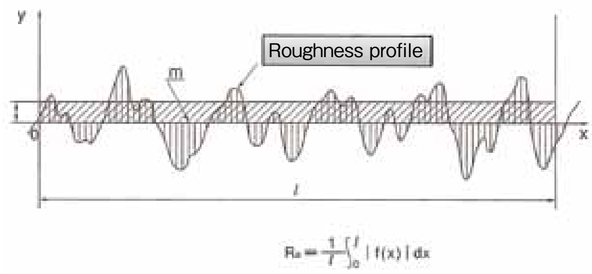
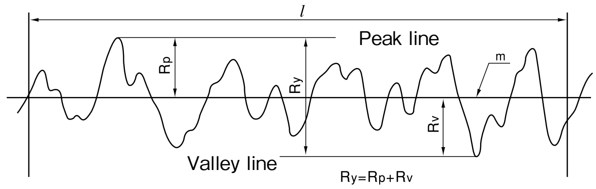


Figure1　Type of surface roughness: calculated average roughness (Ra)



Note: In calculating Ry, only the average roughness profile area in reference length should be used, because too high or low peaks might be caused by abnormal reason such as scratch.

Figure2　Type of surface roughness: maximum peak (Rmax)

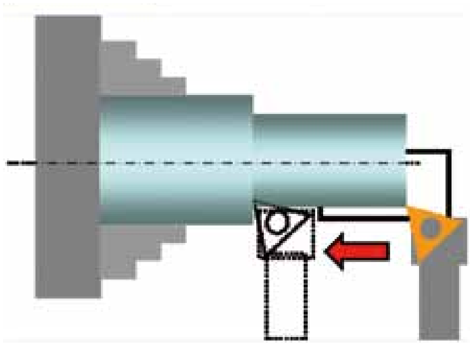


Figure3　Machining of outside diameter

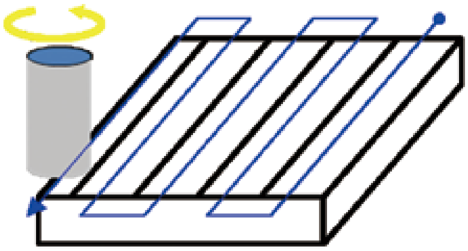


Figure4　Machining of a surface

5. Direction of Molded Products

Molded PTFE products have various directions depending on their molding methods, and the direction influences the physical properties. One of the common molding methods for PTFE is the compression molding method, as shown in Figure 5.

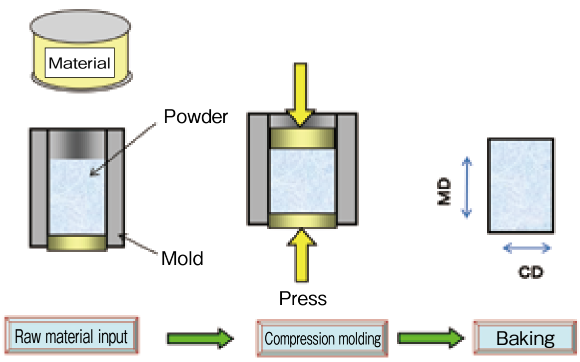


Figure5　The compression molding method

In the compression molding method, the material is placed in a mold and force is applied from both above and below the mold to press the material together. This generates directionality. The direction toward the compressed side in the material at the time of molding is called the molding direction (MD), while the direction perpendicular to MD is called the cross-sectional direction (CD).

Some PTFE materials are filled PTFE whose material is mixed with filler. Since fibrous filler orients during molding, and has markedly different physical properties from those of PTFE, filled PTFE should be designed and used with caution.

The following are characteristics that are changed in filled PTFE.

Compression-creep characteristics:

　The MD value becomes greater than the CD value.

Tensile strength and elongation:

　MD tensile strength becomes greater than CD tensile strength. CD elongation becomes greater than MD elongation.

Coefficient of linear expansion:

　The MD value becomes greater than the CD value.

When material shapes are sleeves and rods, the molding direction can be visually confirmed, and so the processing can be started based on the direction. However, when the material shapes are plates and complex processing is required, it is necessary to visualize the direction including marking the direction during the initial processing stage.

6. Conclusion

PTFE is chemically inactive, has excellent chemical resistance, can be used at a wide range of temperature, and has the lowest friction coefficient among solid materials, and so has been used for various purposes. Also, PTFE is much easier to machine than metals. It is also relatively softer than other resins and has good affinity when combined with other materials for use.

Recently, many PTFE products have also been used in the precision-instrument industry, and so stricter dimensional accuracy is required. We will develop machining techniques in line with the accelerating progress of machine tools and industrial tools. To do this, we will ask users and manufacturers for their requests for dimensional accuracy and tolerances according to their intended uses.

7. References

1. *Valqua Handbook*, Technology Ver., September 2010
2. *Fluororesin DuPont™ Teflon Handbook*, Du Pont-Mitsui Fluorochemicals Company, Ltd.
3. JIS K 6884-1971

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Correction and apology

VALQUA would like to announce and apologize for a partial correction to "Explanation on PTFE Linear Expansion Coefficient," 3. Example calculation for dimensional correction in VALQUA Technology New Summer No. 31.

Incorrect: Dimensional change

Incorrect: Dimensional change $= 1000 \times (100 - 0) \times 20 \times 10^{-5} = 20$

Correct: Dimensional change $= 1000 \times (0 - 25) \times 20 \times 10^{-5} = -5$

Therefore, the length at 0° C is 995 mm (shrunk).