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Technical Paper

Calculation of Oil Retention Volume - Vo

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Abstract

Engineers have been using the Mr2 and Rvk parameters to calculate "Oil Retention Volume" (Vo) of a plateau honed surface. Two different equations for the calculation of Vo have been used throughout the industry, causing some confusion as to which one is correct.

Dimensional analysis of the equations proves the two equations are equivalent, if the appropriate units are chosen.

$$Vo = \frac{(100 - Mr2)}{2000} \cdot Rvk \frac{mm^3}{cm^2} \qquad \text{Eq.1}$$

$$Vo = \frac{(100 - Mr2)}{200} \cdot Rvk \frac{\mu m^3}{\mu m^2} \qquad \text{Eq.2}$$

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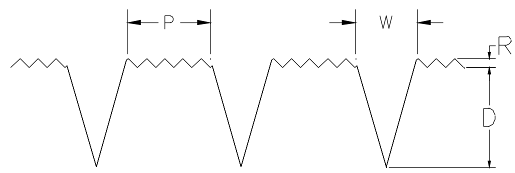
<u>Introduction</u>

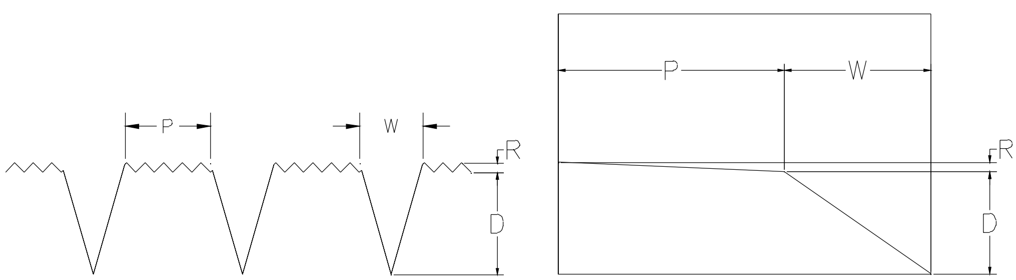
The benefit of a plateau honed surface profile has been known for many years. Most tribologists will agree the ideal bearing surface would exhibit a smooth surface (plateau) with relatively deep scratches (valleys) in a uniform cross-hatch pattern. The smooth plateau surface acts as a wear resistant bearing surface and the deep scratches act as oil retention reservoirs.

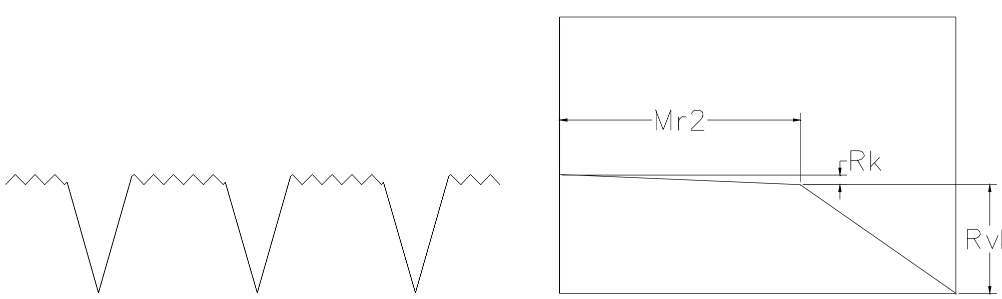
The four main characteristics of the plateau surface are;

1) roughness of the plateau - R
2) percentage of plateauness - P
3) depth of the oil grooves - D
4) volume retained in the oil - Vo grooves.



Until the introduction of the Rk family of parameters (DIN 4776), there was not an efficient method of measuring the plateau characteristics. The Rk parameter quantifies the roughness of the plateau, the Mr2 parameter quantifies the amount of bearing area and the Rvk parameter quantifies the average groove depth.





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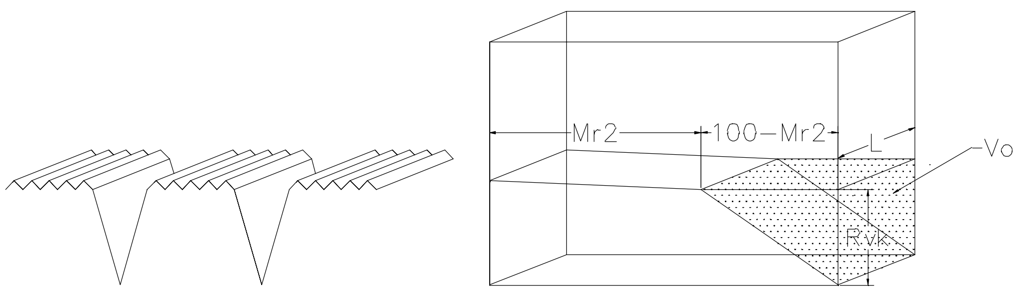
As the Rk family of parameters does not specifically address the volume of oil potentially retained in the valleys, engineers have calculated Vo using the Mr2 and Rvk parameters and Equation 1.

$$Vo = \frac{(100 - Mr2)}{2000} \cdot Rvk \qquad \text{Eq. 1}$$

However, some measuring instruments calculate the Vo parameter using Equation 2. (This parameter is labeled Fr2 on some older model instruments like the Hommel T4000.) The two equations have caused some confusion about which is correct. The answer can be found through careful examination of the units used in each equation.

$$Vo = \frac{(100 - Mr2)}{200} \cdot Rvk \qquad \text{Eq. 2}$$

To solve this dimensional problem, we start with the origin of the equations - the bearing area curve. For clarity, the profile and bearing area curve have been extruded to three dimensions. The Mr2 parameter quantifies the area of the plateaus on the profile commonly refered to as "bearing area". The Vo parameter is the extruded triangular area shown in the figure below.



Since our surface finish measurements are actually two dimensional, Mr2 should be expressed in units of percent (%) bearing length. In practice %-bearing length is implicitly multiplied by the unit length L, giving us the familiar units of % bearing area having units of $\mu m^2/100\mu m^2$. To show this, we introduce bearing length λ in Equation 3.

$$\%Area = \frac{Area}{100 Area} = \frac{\lambda \cdot L}{100\lambda \cdot L} = \frac{\lambda\mu m \cdot L\mu m}{100\lambda\mu m \cdot L\mu m} = \frac{\lambda L\mu m^2}{100\lambda L\mu m^2} = \frac{\mu m^2}{100\mu m^2} \qquad \text{Eq. 4}$$

Since Mr2 is expressed in units of area, we need not be concerned with the length L Equation 5.

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$$Vo = \frac{1}{2}(100 - Mr2)\frac{\mu m^2}{100\mu m^2} \cdot Rvk\mu m = \frac{(100 - Mr2)}{200} \cdot Rvk\frac{\mu m^3}{\mu m^2} \qquad \text{Eq.5}$$

Therefore the units for Equation 1 must be $\mu m^3/\mu m^2$ or μm. The units sited in several popular documents using Equation 2 are mm^3/cm^2. We can convert the units from Equation 1 as follows

$$\frac{\mu m^3}{\mu m^2} = \frac{\mu m^3}{\mu m^2} \cdot \frac{mm^3}{1000^3\,\mu m^3} \cdot \frac{1000^2\,\mu m^2}{mm^2} \cdot \frac{10^2\,mm^2}{cm^2} = \frac{mm^3}{10cm^2}$$

Plugging these units in to equation 2 yields

$$Vo = \frac{(100 - Mr2)}{200} \cdot Rvk\frac{mm^3}{10cm^2} = \frac{(100 - Mr2)}{2000} \cdot Rvk\frac{mm^3}{cm^2}$$

Conclusion

Equations 1 and 2 are equivalent if the appropriate units are chosen.

$$Vo = \frac{(100 - Mr2)}{2000} \cdot Rvk\frac{mm^3}{cm^2} \qquad \text{Eq.1}$$

$$Vo = \frac{(100 - Mr2)}{200} \cdot Rvk\frac{\mu m^3}{\mu m^2} \qquad \text{Eq.2}$$

As neither equation has been adopted by a national standards organization, the choice is arbitrary. Equation 2 however has the advantage of current use in many popular instruments.

References

1. Mummery, Leigh – "Surface Texture Analysis the Handbook", Hommelwerke GmbH (1990).

2. Trautwein, Rudolf – "Characteristic Values for Determining and Evaluating the Surface of Cylinder Bores", Mahle, Technische Informationen, Folge 21 (1978).

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