Precision Stripe Coating by Non-meniscus Guide Slot Die

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- Non Meniscus guide type \( \rightarrow \) Direct groove type
- Tungsten Carbide
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- Super polishing and high precision
- Conclusion
Slot Die Overview

- Tungsten Carbide lips
- Stainless steel lips
- Stainless steel body
What is Slot Die?

- Functional coating apparatus used in roll to roll and batch coating applications
Stripe coating by Slot Die
Stripe coating by Slot Die

OPV, OLED lighting
Must be same width.
Hot Spot Issue
Stripe Coating with shim

Cavity

Stripe shim
Stripe Coating with shim
The quality of slits

All slits must be same width.
Precision cutting: Straightness, same dimension
Cutting quality: smoothness, sharp edge

Sharp corner edge: If it is not sharp, leakage and diffusion happens.
If the quality of slits are not good, the width of stripes are not in same.

Problems
- Hot spot issue on OPV
- Cross talk issue
- Conduction (Short) issue

Another issue: Shim vibration
Stripe Coating with shim + Meniscus guide

Meniscus guide may prevent shim vibration.
Meniscus guide
Meniscus guide is not perfect to obtain high precision stripe coat.
Non Meniscus guide type → Direct groove type

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Tungsten Carbide. \( R : 2\text{-}3\mu m \)

(Stainless steel. \( R : 20\mu m \))

Shim. \( R : 20\mu m \)

vibration
Precision Stripe Coating by Non-meniscus Guide Slot Die

High precision polishing process

90 degree side wall

Edge R : 2-3um $\rightarrow$ 1um less

Corner R : 200um $\rightarrow$ 15um
Precision Stripe Coating by Non-meniscus Guide Slot Die

Market Demand and Our Activities “Fluid analysis”

We can analyze inner flow of the Slot Die. We can also evaluate following items:
- Width direction uniformity of the discharge velocity
- Inner Pressure
- Stream Line, etc.

Considerable Factor
- Fluid Density
- Fluid Viscosity
- Gravity

Fig. Model of Slot Die inner part

Analysis Model

mesh: 0.8M → 1M  
(length of slot die: class: 700mmL)

The plane of symmetry

Analysis result (thickness prediction)

Plot on the graph
1) die ≤ 500L: plotting interval 0.5mm
2) die > 500L: plotting interval 1mm

CAE capability
Fluid analysis
What is tungsten carbide?

Tungsten Carbide

Ceramics

Tungsten Carbide (WC) + Binder Phase: Co (Ni, Cr)

High Hardness Steel

Stainless Steel

Hardness

Toughness
Why Tungsten Carbide?

Tungsten carbide is one of the metal which is the hardest in industrial metal. The reason why is different in hardness with the same metal is a difference of an orbit used for a metallic bond.

The metal, which is affected by the non directionality S orbit, is hard to cut the metallic bond. Therefore such kind of metals show high tenacity by the transformation.

On the other hand, the metal, which is affected by directionality P orbit, show low tenacity. Because big energy is necessary for the expansion and contraction by transformation. Tungsten Carbide, which obtain p orbit of carbon by increasing carbon as impurities, became harder than other metals including tungsten itself.
Tungsten Carbide

Hard metal properties

Slot die lips for wear resistance

Computer analysis introduces a case study of lip wear for critical process control. This study helps in understanding geometric modeling of slot die lips and helps support the necessity of wear resistant material for slot die lips. Additionally this analysis shows the resulting cases of protection against corrosive fluids.

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Tungsten Carbide</th>
<th>SUS316L S31603</th>
<th>SUS304 S30400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td></td>
<td>14.5</td>
<td>7.98</td>
<td>7.93</td>
</tr>
<tr>
<td>Hardness</td>
<td>Hv</td>
<td>1950</td>
<td>145(max500)</td>
<td>150(max510)</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>W/m°C</td>
<td>71</td>
<td>16.3</td>
<td>16.3</td>
</tr>
<tr>
<td>Thermal Expansion coffecient</td>
<td>xE-6/°C</td>
<td>5.3</td>
<td>16</td>
<td>17.3</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td>Gpa</td>
<td>580</td>
<td>193</td>
<td>193</td>
</tr>
<tr>
<td>Bending Strength</td>
<td>GPA</td>
<td>3.8</td>
<td>0.559</td>
<td>0.578</td>
</tr>
</tbody>
</table>
Comparison of grain size

Tungsten Carbide for Slot Die

Ultra Micro Grain Series

Micro Grain Series

Comparison to Stainless steel

- S31603 (SUS316L)
- S30400 (SUS304)
Coating Lip at die exit

Comparison of Stainless and Carbide Edge Sharpness
Just after final mechanical grinding

Lip Edge of **Tungsten Carbide**

Lip Edge of **Stainless Steel**
3 years usage in Li-Ion Battery production line

Tungsten Carbide Lip
Top
Wear: 36.22µm
3µm→36µm
11µm/year

Stainless Steel Lip
Top
Wear: 392.34µm
30µm→390µm
120µm/year

Still same

Changed

Comparison to Stainless steel
Weakness of Stainless Steel Lip

It is easy to get scratches on the top surface of Lips.

This photograph shows the situation of scratches just after the first test run.

Stainless steel is not suitable for the scratch.

It will be streak issue on the coated layer.
Theoretical Coating window

Sharp edge and process window

Stable coating condition

Capillary number
(viscosity x coating speed / surface tension)
Capillary number vs. Wet thickness / coating gap

- Stable coating
- Upstream leakage
- Air entrainment
- Bead break
- Min. limit thickness

Capillary number (viscosity x coating speed / surface tension)
Stable coating
Upstream leakage
Super finish grinding of tungsten carbide

Millar Face

Below $Rz0.1\mu m$
# Super finish grinding

## Conventional vs Our mechanical grinding

<table>
<thead>
<tr>
<th>Carbide part</th>
<th>Stainless part</th>
<th>Carbide part</th>
<th>Stainless part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfcomer SE-2300</td>
<td>Surfcomer SE-2300I</td>
<td>Surfcomer SE-2300</td>
<td>Surfcomer SE-2300I</td>
</tr>
<tr>
<td>Date</td>
<td>01/08/21 15:50</td>
<td>Date</td>
<td>01/08/21 13:26</td>
</tr>
<tr>
<td>V.mag.</td>
<td>20000</td>
<td>V.mag.</td>
<td>20000</td>
</tr>
<tr>
<td>H.mag.</td>
<td>100</td>
<td>H.mag.</td>
<td>100</td>
</tr>
<tr>
<td>Length</td>
<td>0.4 mm</td>
<td>Length</td>
<td>0.4 mm</td>
</tr>
<tr>
<td>Drive speed</td>
<td>0.1 mm/s</td>
<td>Drive speed</td>
<td>0.1 mm/s</td>
</tr>
<tr>
<td>Cutoff</td>
<td>0.8 mm</td>
<td>Cutoff</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Ra</td>
<td>0.08 μm</td>
<td>Ra</td>
<td>0.12 μm</td>
</tr>
<tr>
<td>Rmax</td>
<td>0.76 μm</td>
<td>Rmax</td>
<td>1.19 μm</td>
</tr>
<tr>
<td>P profile</td>
<td><img src="image" alt="P profile" /></td>
<td>P profile</td>
<td><img src="image" alt="P profile" /></td>
</tr>
</tbody>
</table>

| Rz 0.79 μm | Rz 1.19 μm |

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<td>Surfcomer SE-2300</td>
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<tr>
<td>Date</td>
<td>01/08/20 16:24</td>
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<td>V.mag.</td>
<td>50000</td>
</tr>
<tr>
<td>H.mag.</td>
<td>100</td>
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<td>Length</td>
<td>0.4 mm</td>
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<tr>
<td>Drive speed</td>
<td>0.1 mm/s</td>
</tr>
<tr>
<td>Cutoff</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Ra75</td>
<td>0.008 μm</td>
</tr>
<tr>
<td>Rmax</td>
<td>0.074 μm</td>
</tr>
<tr>
<td>P profile</td>
<td><img src="image" alt="P profile" /></td>
</tr>
</tbody>
</table>

| Rz 0.074 μm | Rz 0.128 μm |
Market Demand and Our Activities “Slot Die Precision”

The results of the straightness (Example)

① The slit surface (High precision 1600L)

<table>
<thead>
<tr>
<th>Straightness 1</th>
<th>0.75μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightness 2</td>
<td>0.75μm</td>
</tr>
<tr>
<td>Straightness 3</td>
<td>1.25μm</td>
</tr>
</tbody>
</table>

② The slit surface (Normal precision 1500L)

<table>
<thead>
<tr>
<th>Straightness 1</th>
<th>2.25μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightness 2</td>
<td>2.50μm</td>
</tr>
<tr>
<td>Straightness 3</td>
<td>2.25μm</td>
</tr>
</tbody>
</table>
In House Experiment is also used high precision machine.
Conclusion

Precision stripe coating: direct groove type is suitable.

Slit quality: Sharp edge, Smoothness, Straightness, reliable slit dimension

Possible Benefit: Solve issues
- Hot spot issue on OPV
- Cross talk issue
- Conduction (Short) issue

Tungsten carbide is outperform to Stainless steel to maintain precision stripes.