粉末(金屬)射出成型 PIM/MIM

模具材料失效與對策

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PIM/MIM 複雜零件/ 模具精密0.05mm以內

PIM /MIM 產品

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Selected Mechanical Properties of PIM Metals and Alloys (HT=heat treated)							
Material	Composition,wt.%	Density %	Yield Strength Rp0.2	UTS Mpa	Elonga-tion%	Hardness	模具失效狀態
1020 steel	Fe-0.2C	96	185	380	23	-	刮損磨耗與疲勞
4140	Fe-1Cr-0.4C	97	390	580	15	18 HRC	
4140 (HT)	Fe-1Cr-0.4C	93	1240	1380	2	40 HRC	
4340 steel(HT)	Fe-2Cr-1Ni-1Mn-0.4C	96	480	620	6	20 HRC	
4640 steel (HT)	Fe-2Ni-1Mo-0.4C	97	1400	2000	3	30 HRC	
gold,18 ct.	75Au-12.5Ag-12.5Cu	75	108	147	1	66 HRB	粘著磨耗與疲勞裂痕
hastelloy	Ni-28Mo-2Fe	97	350	800	40	30 HRC	
inconel 718 (HT)	Ni-19Cr-18Fe-5Nb-	100	1130	1330	14	-	
	3Mo-1Ti-0.4Al						
invar	Fe-36Ni	98	240	425	40	65 HRB	
iron	Fe	96	105	220	35	50 HRF	
iron-copper steel	Fe-2Cu-0.8C	95	-	700	10	92 HRB	
iron-chromium steel	Fe-1Cr-0.5C	94	-	600	10	90 HRB	
iron-molybdenum	Fe-5Mo	98	210	410	34	66 HRB	
iron-nickel	Fe-2Ni	96	190	345	30	55 HRB	
iron-nickel	Fe-8Ni	96	255	440	24	75 HRB	
iron-nickel	Fe-50Ni	96	170	420	20	50 HRB	
iron-nickel steel	Fe-2Ni-0.5C	94	215	450	20	75 HRB	
iron-nickel steel (HT)	Fe-2Ni-0.5C	94	1230	1230	1	45 HRC	
iron-nickel steel	Fe-2Ni-0.9C	96	450	650	9	90 HRB	
iron-nickel steel (HT)	Fe-7Ni-0.5C	95	1420	1460	1	46 HRC	

PIM/MIM合金粉末特性分類

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Selected Mechanical Properties of PIM Metals and Alloys (HT=heat treated)							
Material	Composition,wt.%	Density %	Yield Strength Rp0.2	UTS Mpa	Elonga-tion%	Hardness	模具失效狀態
iron-phosphorus	Fe-0.6P	99	260	280	2	80 HRB	磨耗磨耗
iron-sillcon	Fe-3Si	99	345	520	25	85 HRB	
iron-sillion	Fe-6.5Si	99	-	375	0	37 HRC	
kovar or F15	Fe-29Ni-17Co	98	350	520	42	60 HRB	粘著磨耗潤磨氧化反應
nickel-iron	Ni-20Fe	91	-	470	31	53 HRB	
niobium superalloy	Nb-10W-10Ta	98	315	440	25	20 HRC	
stainless 17-4 PH	Fe-16Cr-4Ni-4Cu	96	750	900	10	25 HRC	
stainless 17-4 PH (HT)	Fe-16Cr-4Ni-4Cu	96	965	1140	12	35 HRC	
stainless 304L	Fe-18Cr-8Ni	97	240	480	35	85 HRB	
stainless 316L	Fe-17Cr-12Ni-2Mo-2Mn	96	220	510	45	75 HRB	
stainless 316L duplex	Fe-21Cr-9Ni-3Mo-2Mn	95	230	540	43	80 HRB	
stainless 410L (HT)	Fe-11Cr-0.5C	95	410	650	5	20 HRC	
stainless 420 (HT)	Fe-13Cr-1Mn-1Si	92	690	1440	6	47 HRC	
stainless 430	Fe-17Cr-1Mn-1Si-1Ni	93	230	390	25	68 HRB	
stainless 440C (HT)	Fe-17Cr-1Ni-1C	96	410	620	2	43 HRC	

PIM/MIM合金粉末特性分類

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Selected Mechanical Properties of PIM Metals and Alloys (HT=heat treated)							
Material	Composition,wt.%	Density %	Yield Strength Rp0.2	UTS Mpa	Elonga-tion%	Hardness	模具失效狀態
stellite	Co-28Cr-4W-3Ni-1C	99	-	1020	3	40 HRC	粘著磨損
super invar	Fe-32Ni-5Co	96	285	440	40	65 HRB	
titanium	Ti	95	1100	1300	16	-	
Ti-6-4	Ti-6Al-4V	98	800	880	12	35 HRC	
tool steel	Fe-6W-5Mo-4Cr-2V-1C	99	-	2000	0	66 HRC	磨粒磨耗
tungsten heavy alloy	W-8Mo-8Ni-2Fe	100	-	1115	20	-	
tungsten heavy alloy	W-5Ni-2Cu	98	900	1050	10	35 HRC	
tungsten heavy alloy	W-4Ni-1Fe	99	650	1000	20	50 HRA	
tungsten heavy alloy	W-5Ni-2Fe	100	660	930	30	25 HRC	
udimt 700	Ni-18Co-15Cr-5Mo-4Al-3Ti	100	910	1340	14	-	粘著磨耗

PIM/MIM合金粉末特性分類

梧濟工業

PIM/MIM模具鋼機械特性

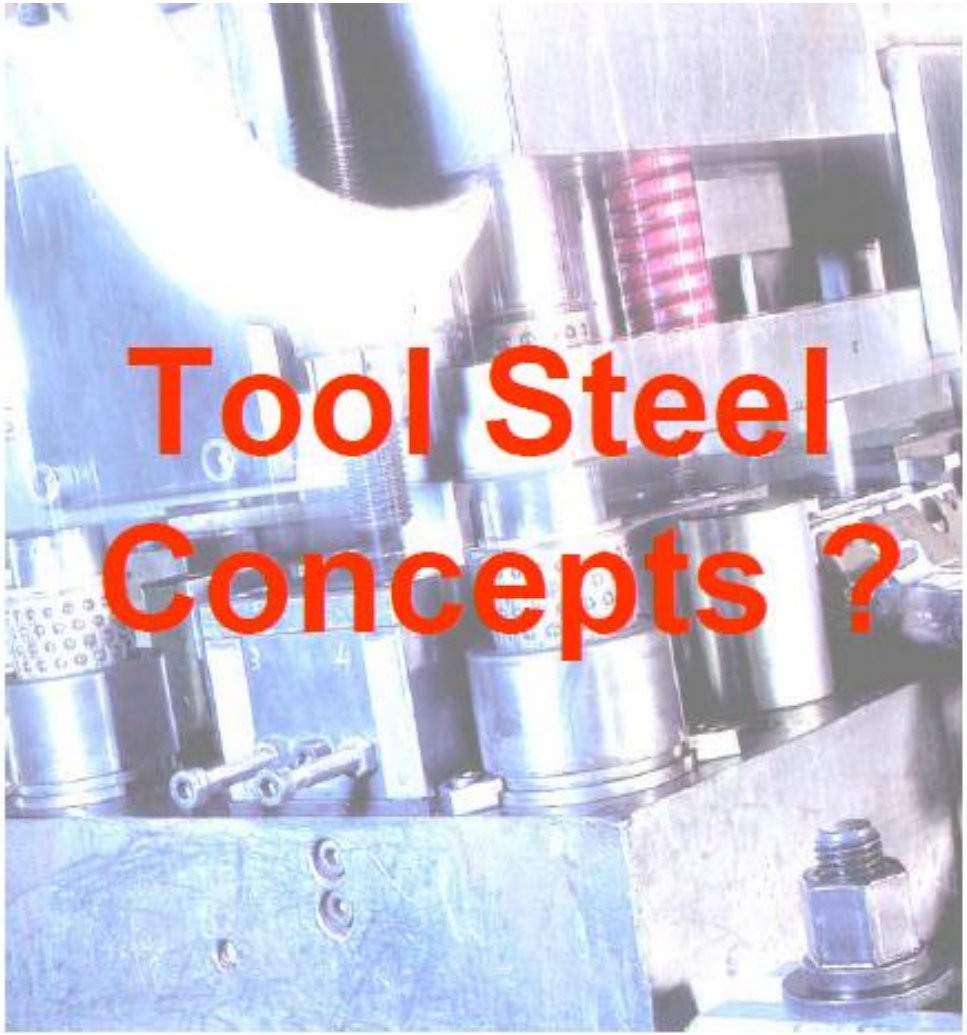
模具典型失效狀態

A **Abrasive Wear**
Erosion of the Matrix

B **Adhesive Wear**
Local Friction Bonding,
Material Transfer

C **Fatigue**
Surface Delamination,
Plastic Deformation → Fatigue
Crack Propagation

D **Tribooxidation**
Chemical Reaction
Tool - Workpiece
Lubricant / Coolant



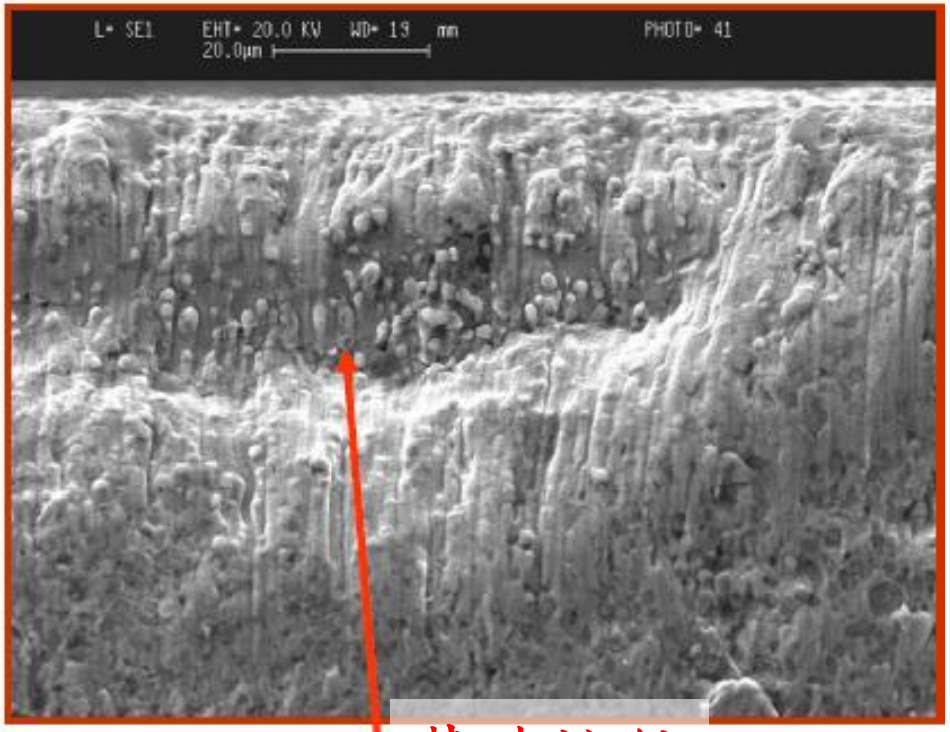
Abrasive Wear
Erosion of the Matrix

刮損磨耗：
基地熔損,熔蝕現象

對策：
強化基地硬度與
碳化物硬度

Tribooxidation
Chemical Reaction
Tool - Workpiece
Lubricant / Coolant

Increased Matrix Strength
Hard Particles (Carbides)



基地熔蝕
Erosion of the Matrix

粘著磨耗

Adhesive Wear

Local Friction Bonding, Material Transfer

局部磨擦冷焊現象

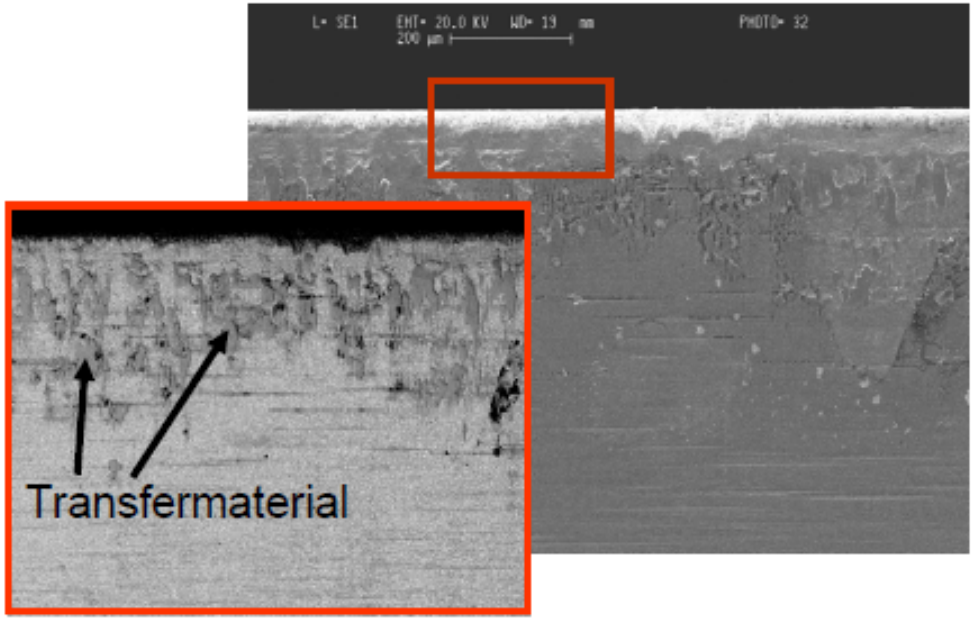
對策：

(1) 強化鋼材基地硬度

(2) 減少碳化物間之空隙

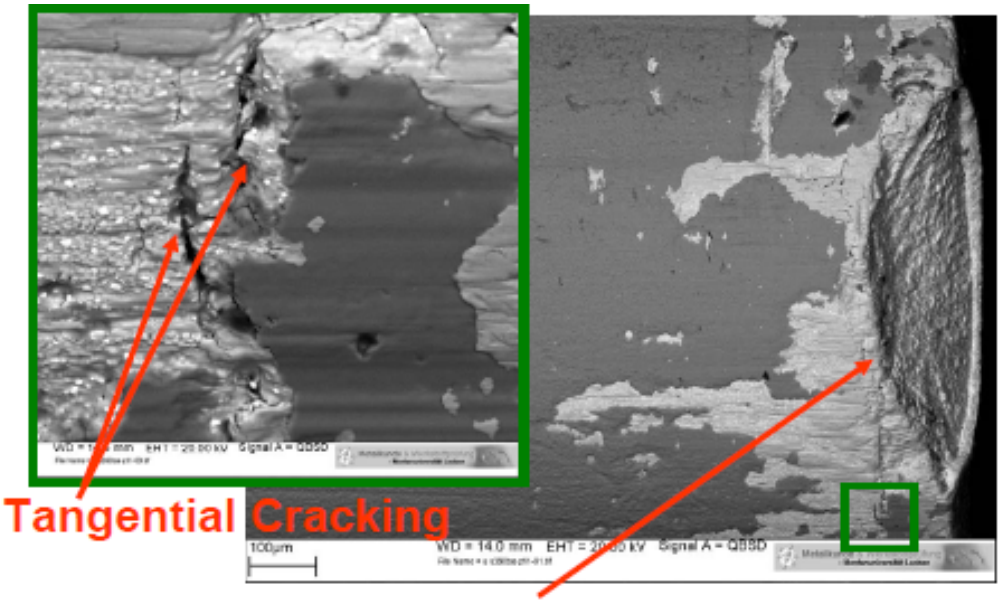
碳化物含量與碳化物的細微化且均勻分佈於基地。

Increased Matrix Strength
Minimized Carbide Spacing
(Fine Carbides, Uniform Distribution, High Carbide Content)



疲勞破裂：
模具接觸面鈍化導致塑性變形，因此疲勞裂痕展開

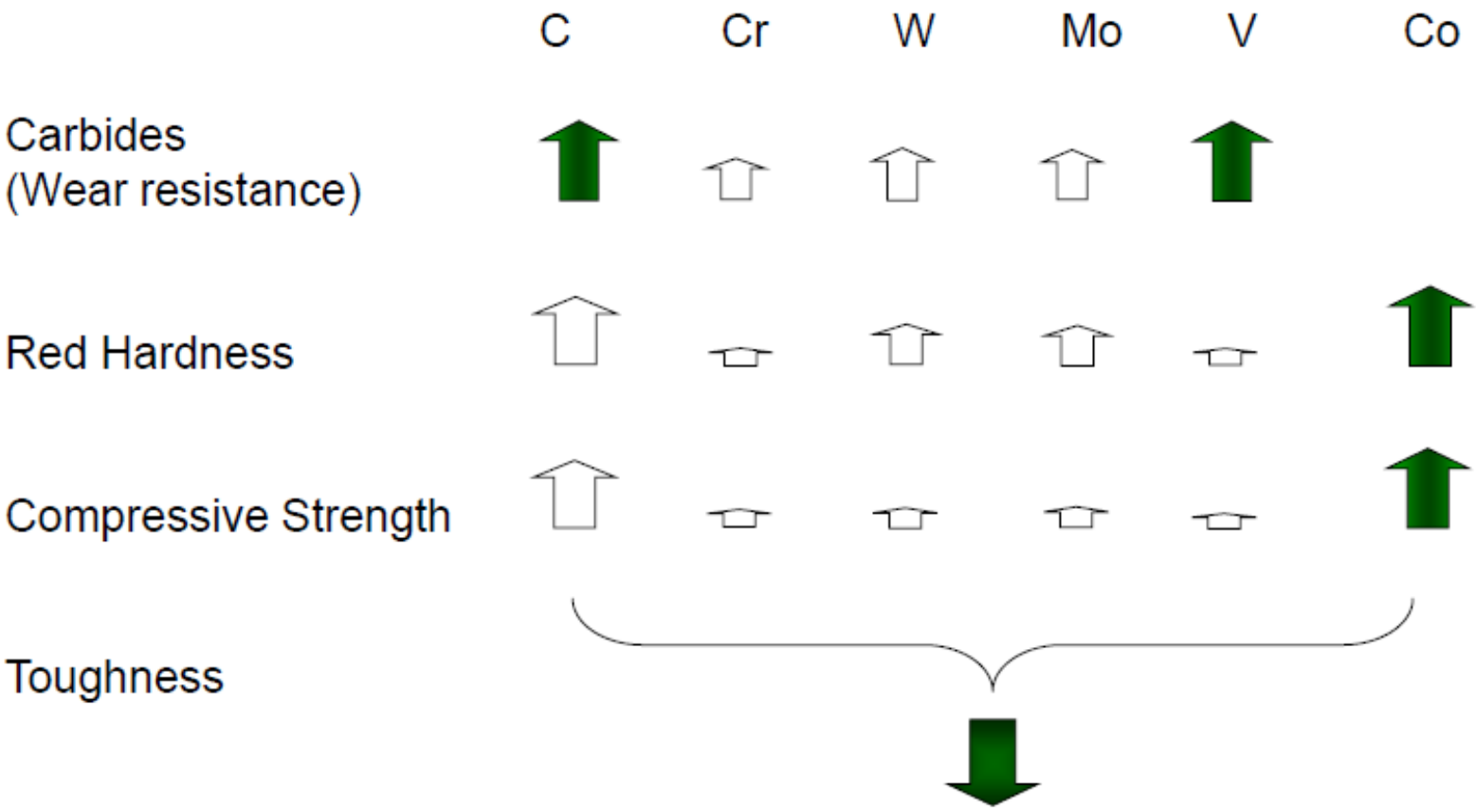
Fatigue
Surface Delamination, Plastic Deformation →Fatigue Crack Propagation



對策：
(1)提高降服強度與延展性
(2)碳化物細微化與均勻分佈
(3)低雜質(非金屬介在物)

**High Yield Strength & Ductility
Fine and Uniform Structure
Cleanliness (Minimized Internal Defect Size → Carbides,NMI)**

PIM/MIM 模仁鋼材料合金選擇



PIM/MIM 模仁材料合金選擇

DIN	AISI	C	W	Mo	V	Co
HS 2-9-2	M7	1	2	9	2	
HS 1-4-2	M52	0,9	1	4	2	
HS 2-9-1-8	M42	1	2	10	1	8
HS 6-5-2 C	~M2	0,9	6	5	2	
HS 6-5-3	M3 / C. II	1,2	6	5	3	
HS 6-5-2-5	~M35	0,9	6	5	2	5

MIM 精密模具鋼材選用對策

- 模腔/型芯/流道 = 耐磨合金 HRC:60以上
- 關閉角配件/滑塊 = 耐磨合金HRC:60/鍍層
- 模座 = 高硬度 HRC:38 or HRC:50
- 應力分佈- 加工精度/抗彎強度

模仁(型腔)與模座抗壓強度之比較

高強度，尺寸精度維持時間長

模具組件	模具材料	硬度(HRC)	抗壓強度	材料特性
型腔材料	SKD-11 HSS PM HSS	60-62 60-64 60-67	2800~3800 N/mm^2	高尺寸穩定性 高耐粘著磨耗性
模框	H13	52-54	2000-2400 N/mm^2	高尺寸穩定性
模座	H13 1.2714	50-52 38-42	1400-1800 N/mm^2	高韌性 高疲勞強度

模仁(型腔)與模座抗壓強度之比較

模座易變形導致模仁破裂，精度不佳

模具組件	模具鋼材料	硬度(HRC)	抗壓強度	材料特性
型腔材料	SKD-11 HSS PM HSS	60-62 60-64 60-67	2800~3000 N/mm^2	高耐磨性 高硬度
模框	P-20 1.2311	30-33	800~1000 N/mm^2	易切削 低強度
模座	1050 1055	18-20	600~800 N/mm^2	易切削 易變形

模具表面鍍層對磨擦係數的影響

M.I.M粉末種類	磨耗機構	建議鍍層
含Ni, Ti, Al, Cu,Cr不銹鋼系,鈦合金	粘著磨耗	DLC, (WC/C),CrN
含Fe, Co,工具鋼粉, 高速鋼粉	磨粒磨耗 刮損磨耗	TiC, TiCN, SiAlON, TiAlN

結論

M.I.M粉末成型模具材料之選用必需滿足以下工藝要求:

1. 含釩(V)，高鉻(Cr)之工具鋼以對抗不銹鋼之粘著磨耗，硬度HRC:60~62

   EX: SKD-11/HSS/PM HSS

2. 含Co,W,Mo之工具鋼對抗刮損磨耗，硬度HRC:62-66

   EX: HSS/PM HSS

3. 選擇高強度之模座材料以提高模具結構強度

   EX:1.2344,1.2714

4. 嚴謹的熱處理工藝流程以確保工具鋼相變態之完整性，以提高尺寸穩定性與抗時效變寸。

Thank you