INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 11, Issue 4 - V11I4-1208)
Available online at: https://www.ijariit.com

Optimal Material Selection for Injection Moulding Die

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ABSTRACT

Choosing the right material for making injection molding dies is very important, as it affects how well the mold performs, how long it lasts, and how much it costs to maintain. Since the die goes through high pressure and temperature again and again during each molding cycle, it must be made of strong materials that can handle heat, resist wear, and stay dimensionally stable. In this study, I looked into the important factors to consider while selecting the die material, like mold life, how easy it is to machine, resistance to corrosion, and how well it works with different types of plastic. Some commonly used materials like P20 tool steel, H13 tool steel, and beryllium copper alloys are compared based on their properties and usage. I have also included details about special coatings and surface treatments that improve the life and performance of these materials. Overall, with proper material selection based on both technical and cost aspects, manufacturers can improve efficiency, reduce downtime, and increase the lifespan of injection molds.

Keywords: *Injection Moulding, Die Material Selection, Tool Steels, H13 Steel, P20 Steel, 718 Alloy, 2378 Alloy, Nak80, S7 Steel, Dear Method, Data Envelopment Analysis, Multi-Criteria Decision Making, Thermal Conductivity, Wear Resistance, Machinability, Mold Performance, Material Comparison, Mold Life, Manufacturing Efficiency.*

1.0 INTRODUCTION

Injection moulding is a commonly used method in industries to produce plastic parts in large quantities. In this process, the injection moulding die (or mold) plays a crucial role in shaping the final product and maintaining its dimensional accuracy. The die is exposed to high pressure, elevated temperatures, and repeated mechanical and thermal stresses during each moulding cycle. Therefore, selecting the right material for the die is very important to ensure good performance, long tool life, and cost-effectiveness. As an engineering student, I have understood that choosing a suitable die material involves considering several important properties. These include high hardness and wear resistance for durability, good thermal conductivity for quick cooling, and dimensional stability for maintaining precision. Additionally, the material should be easy to machine, resistant to corrosion and thermal fatigue, and compatible with the type of plastic used. For example, P20 tool steel is commonly used for general-purpose Mold because it offers a good balance of properties and is easy to machine. H13 tool steel is more suitable for high-volume production as it can withstand higher temperatures. In some cases, beryllium-copper alloys are used in inserts where fast heat dissipation is needed. The final selection also depends on factors like Mold complexity, part design, production volume, and budget. A well-chosen material ensures better product quality, reduces downtime, and extends Mold life. By understanding the service conditions and properties of materials, we can make informed decisions during Mold design. Overall, proper material selection is a key factor in achieving efficient, reliable, and economical injection moulding operations.

2.0 MATERIAL PROPERTIES

2.1 H 13 TOOL STEEL

Physical Properties	Metric	English
Density	7.80 g/cc	0.282 lb/inÂ^3

Mechanical Properties	Metric	English
Hardness, Rockwell C	28 - 30	28 - 30
	31 - 33	31 - 33
	39 - 41	39 - 41
	45 - 47	45 - 47
	49 - 51	49 - 51
	51 - 53	51 - 53
	51 - 53	51 - 53
	52 - 54	52 - 54
Tensile Strength, Ultimate	1990 MPa	289000 psi
Tensile Strength, Yield	1650 MPa	239000 psi
Elongation at Break	9.00%	9.00%
Modulus of Elasticity	210 GPa	30500 ksi
Bulk Modulus	160 GPa	23200 ksi
Poissons Ratio	0.3	0.3
Machinability	50%	50%
Shear Modulus	81.0 GPa	11700 ksi

Thermal Properties	Metric	English
CTE, linear	11.0 Âµm/m-Â°C	6.11 Âµin/in-Â°F
-	@Temperature 25.0 - 95.0 Â°C	@Temperature 77.0 - 203 Â°F
	11.5 Âµm/m-Â°C	6.39 Âµin/in-Â°F
	@Temperature 25.0 - 205 Â°C	@Temperature 77.0 - 401 Â°F
	12.4 Âµm/m-Â°C	6.89 Âµin/in-Â°F
	@Temperature 25.0 - 540 Â°C	@Temperature 77.0 - 1000 Â°F
Specific Heat Capacity	0.460 J/g-Â°C	0.110 BTU/lb-Â°F
	@Temperature 0.000 - 100 Â°C	@Temperature 32.0 - 212 Â°F
Thermal Conductivity	24.3 W/m-K	169 BTU-in/hr-ftÂ^2-Â°F
-	@Temperature 215 Â°C	@Temperature 419 Â°F
	24.3 W/m-K	169 BTU-in/hr-ftÂ^2-Â°F
	@Temperature 475 Â°C	@Temperature 887 Â°F
	24.4 W/m-K	169 BTU-in/hr-ftÂ^2-Â°F
	@Temperature 350 Â°C	@Temperature 662 Â°F
	24.7 W/m-K	171 BTU-in/hr-ftÂ^2-Â°F
	@Temperature 605 Â°C	@Temperature 1120 Â°F

Processing Properties	Metric	English
Processing Temperature	540 - 650 Â°C	1000 - 1200 Â°F
	995 - 1040 Â°C	1820 - 1900 Â°F
Annealing Temperature	850 - 870 Â°C	1560 - 1600 Â°F
	@Time 14400 sec	@Time 4.00 hour

Component Elements Properties	Metric	English
Carbon, C	0.32 - 0.40 %	0.32 - 0.40 %
Chromium, Cr	5.13 - 5.25 %	5.13 - 5.25 %
Iron, Fe	>= 90.9 %	>= 90.9 %
Molybdenum, Mo	1.33 - 1.4 %	1.33 - 1.4 %
Silicon, Si	1.00%	1.00%
Vanadium, V	1.00%	1.00%

Descriptive Properties	
Stress Relieving Temperature	600 - 650Â°C for 2 hours (approx.)

2.2 718 Alloy

Physical Properties	Metric	English
Density	8.25 g/cc	0.298 lb/inÂ³

Mechanical Properties	Metric	English
Hardness, Rockwell C	25 - 35	25 - 35
	42 - 48	42 - 48
Tensile Strength, Ultimate	1480 MPa	215000 psi
	1380 MPa	200000 psi
_	@Temperature 427 Â°C	@Temperature 800 Â°F
	1450 MPa	210000 psi
	@Temperature 204 Â°C	@Temperature 400 Â°F
Tensile Strength, Yield	1170 MPa	170000 psi
	1030 MPa	150000 psi
_	@Temperature 427 Â°C	@Temperature 800 Â°F
	1100 MPa	160000 psi
	@Temperature 204 Â°C	@Temperature 400 Â°F
Elongation at Break	25%	25%

Thermal Properties	Metric	English
CTE, linear	12.3 Âµm/m-Â°C	6.85 Âµin/in-Â°F
_	@Temperature 100 Â°C	@Temperature 212 Â°F
	13.1 Âµm/m-Â°C	7.30 Âµin/in-Â°F
	@Temperature 250 Â°C	@Temperature 482 Â°F
	13.86 Âµm/m-Â°C	7.700 Âµin/in-Â°F
	@Temperature 500 Â°C	@Temperature 932 Â°F
	16.74 Âµm/m-Â°C	9.300 Âµin/in-Â°F
	@Temperature 900 Â°C	@Temperature 1650 Â°F
Specific Heat Capacity	0.520 J/g-Â°C	0.124 BTU/lb-Â°F
_	@Temperature 260 Â°C	@Temperature 500 Â°F
	0.700 J/g-Â°C	0.167 BTU/lb-Â°F
	@Temperature 538 Â°C	@Temperature 1000 Â°F
	0.725 J/g-Â°C	0.173 BTU/lb-Â°F
	@Temperature 399 Â°C	@Temperature 750 Â°F
	0.900 J/g-Â°C	0.215 BTU/lb-Â°F
	@Temperature 468 Â°C	@Temperature 875 Â°F
Thermal Conductivity	13.7 W/m-K	95.0 BTU-in/hr-ftÂ²-Â°F
_	@Temperature 260 Â°C	@Temperature 500 Â°F
	18.0 W/m-K	125 BTU-in/hr-ftÂ²-Â°F
	@Temperature 538 Â°C	@Temperature 1000 Â°F
	23.8 W/m-K	165 BTU-in/hr-ftÂ²-Â°F
	@Temperature 816 Â°C	@Temperature 1500 Â°F
	26.7 W/m-K	185 BTU-in/hr-ftÂ²-Â°F

	@Temperature 1090 Â°C	@Temperature 2000 Â°F
Melting Point	1260 - 1343 Â°C	2300 - 2449 Â°F
Solidus	1260 Â°C	2300 Â°F
Liquidus	1343 Â°C	2449 Â°F

Component Elements Properties	Metric	English
Aluminum, Al	1.2 - 1.8 %	1.2 - 1.8 %
Boron, B	<= 0.0080 %	<= 0.0080 %
Carbon, C	<= 0.060 %	<= 0.060 %
Chromium, Cr	17 - 21 %	17 - 21 %
Cobalt, Co	8.0 - 10 %	8.0 - 10 %
Iron, Fe	8.0 - 10 %	8.0 - 10 %
Manganese, Mn	<= 0.35 %	<= 0.35 %
Molybdenum, Mo	2.5 - 3.1 %	2.5 - 3.1 %
Nickel, Ni	45.002 - 57.55 %	45.002 - 57.55 %
Niobium, Nb (Columbium, Cb)	4.75 - 5.8 %	4.75 - 5.8 %
Phosphorus, P	<= 0.020 %	<= 0.020 %
Silicon, Si	<= 0.35 %	<= 0.35 %
Sulfur, S	<= 0.010 %	<= 0.010 %
Titanium, Ti	0.50 - 1.0 %	0.50 - 1.0 %
Tungsten, W	0.50 - 1.5 %	0.50 - 1.5 %

2.3 718H

Physical Properties	Metric	English
Density	7.81 g/cc	0.282 lb/inÂ³
	7.75 g/cc	0.280 lb/inÂ³
-	@Temperature 200 Â°C	@Temperature 392 Â°F

Mechanical Properties	Metric	English
Hardness, Brinell	325	325
	340 - 380	340 - 380
	450	450
	500	500
Tensile Strength, Ultimate	979 MPa	142000 psi
	@Thickness 25.4 mm, Temperature 200 Â°C	@Thickness 1.00 in, Temperature 392 Â°F
	1080 MPa	156000 psi
	@Diameter 25.4 mm	@Diameter 1.00 in
Tensile Strength, Yield	827 MPa	120000 psi
-	@Diameter 25.4 mm	@Diameter 1.00 in
	986 MPa	143000 psi
	@Diameter 25.4 mm	@Diameter 1.00 in
Modulus of Elasticity	205 GPa	29700 ksi
	200 GPa	29000 ksi
-	@Temperature 200 Â°C	@Temperature 392 Â°F
Impact Test	30.0 J	22.1 ft-lb
-	@Diameter 25.4 mm,	@Diameter 1.00 in,
-	Temperature 20.0 Â°C	Temperature 68.0 Â°F
	130 J	95.9 ft-lb
	@Diameter 25.4 mm, Temperature 200 Â°C	@Diameter 1.00 in, Temperature 392 Â°F

Thermal Properties	Metric	English
CTE, linear	12.7 Âµm/m-Â°C	7.06 Âµin/in-Â°F
	@Temperature 20.0 - 200 Â°C	@Temperature 68.0 - 392 Â°F
Specific Heat Capacity	0.460 J/g-Â°C	0.110 BTU/lb-Â°F
	@Temperature 20.0 Â°C	@Temperature 68.0 Â°F
Thermal Conductivity	29.1 W/m-K	202 BTU-in/hr-ftÂ²-Â°F
	@Temperature 20.0 Â°C	@Temperature 68.0 Â°F
	29.5 W/m-K	205 BTU-in/hr-ftÂ²-Â°F
	@Temperature 200 Â°C	@Temperature 392 Â°F

Component Elements Properties	Metric	English
Carbon, C	0.37%	0.37%
Chromium, Cr	2.00%	2.00%
Iron, Fe	94.72%	94.72%
Manganese, Mn	1.40%	1.40%
Molybdenum, Mo	0.20%	0.20%
Nickel, Ni	1.00%	1.00%
Silicon, Si	0.30%	0.30%
Sulfur, S	0.01%	0.01%

2.4 NAK80 TOOL STEEL

Mechanical Properties	Metric	English
Hardness, Rockwell C	40	40
Tensile Strength, Ultimate	1264 MPa	183400 psi
Tensile Strength, Yield	1018 MPa	147600 psi
	@Strain 0.2 %	@Strain 0.2 %
Elongation at Break	16.10%	16.10%
Reduction of Area	41.90%	41.90%
Modulus of Elasticity	207 GPa	30000 ksi
	@Temperature 23.0 Â°C	@Temperature 73.4 Â°F
Charpy Impact	11.0 J	8.10 ft-lb
	11.5 J	8.50 ft-lb

Electrical Properties	Metric	English
Magnetic Permeability	<= 380	<= 380
Magnetic Coercive Force, H_c	14 Oe	14 Oe
Magnetic Saturation Flux Density, B_{max}	16360 Gauss	16360 Gauss
Magnetic Remanence, B_r	8500 Gauss	8500 Gauss

Thermal Properties	Metric	English
CTE, linear	11.3 Âµm/m-Â°C	6.30 Âµin/in-Â°F
	@Temperature 20.0 - 100 Â°C	@Temperature 68.0 - 212 Â°F
	12.6 Âµm/m-Â°C	7.00 Âµin/in-Â°F
	@Temperature 20.0 - 200 Â°C	@Temperature 68.0 - 392 Â°F
	13.5 Âµm/m-Â°C	7.50 Âµin/in-Â°F
	@Temperature 20.0 - 300 Â°C	@Temperature 68.0 - 572 Â°F
Thermal Conductivity	41.33 W/m-K	286.8 BTU-in/hr-ftÂ²-Â°F
	@Temperature 93.3 Â°C	@Temperature 200 Â°F
	42.19 W/m-K	292.8 BTU-in/hr-ftÂ²-Â°F

	@Temperature 204 Â°C	@Temperature 400 Â°F

Component Elements Properties	Metric	English
Aluminum, Al	1.00%	1.00%
Carbon, C	0.15%	0.15%
Copper, Cu	1.00%	1.00%
Iron, Fe	93.05%	93.05%
Manganese, Mn	1.50%	1.50%
Nickel, Ni	3.00%	3.00%
Silicon, Si	0.30%	0.30%

2.5 4140 ALLOY STEEL

Physical Properties	Metric	English
Specific Gravity	7.83 g/cc	7.83 g/cc
Density	7.83 g/cc	0.283 lb/inÂ³
Mechanical Properties	**Metric**	**English**
Hardness, Rockwell C	27	27
	60	60
Modulus of Elasticity	200 GPa	29000 ksi
Machinability	60 - 65 %	60 - 65 %
Thermal Properties	**Metric**	**English**
CTE, linear	12.22 Âµm/m-Â°C	6.789 Âµin/in-Â°F
	@Temperature 21.0 - 100 Â°C	@Temperature 69.8 - 212 Â°F
Thermal Conductivity	37.7 W/m-K	262 BTU-in/hr-ftÂ²-Â°F
	@Temperature 300 Â°C	@Temperature 572 Â°F
	42.3 W/m-K	294 BTU-in/hr-ftÂ²-Â°F
	@Temperature 200 Â°C	@Temperature 392 Â°F
	42.7 W/m-K	296 BTU-in/hr-ftÂ²-Â°F
	@Temperature 100 Â°C	@Temperature 212 Â°F
Processing Properties	**Metric**	**English**
Processing Temperature	260 Â°C	500 Â°F
	343 Â°C	649 Â°F
	680 Â°C	1260 Â°F
	732 Â°C	1350 Â°F
	743 Â°C	1370 Â°F
	804 Â°C	1480 Â°F
Component Elements Properties	**Metric**	**English**
Carbon, C	0.40%	0.40%
Chromium, Cr	1.00%	1.00%
Iron, Fe	97.15%	97.15%
Manganese, Mn	1.00%	1.00%
Molybdenum, Mo	0.20%	0.20%
Silicon, Si	0.25%	0.25%

2.6 S7 Alloy Steel

Physical Properties	Metric	English
Specific Gravity	7.83 g/cc	7.83 g/cc
Mechanical Properties	**Metric**	**English**
Hardness, Rockwell C	37 - 40	37 - 40
	59 - 61	59 - 61
Tensile Strength, Ultimate	2025 MPa	293700 psi
Tensile Strength, Yield	1520 MPa	220000 psi
	@Strain 0.2 %	@Strain 0.2 %
Elongation at Break	10%	10%
Reduction of Area	28%	28%
Thermal Properties	**Metric**	**English**
CTE, linear	12.59 Âµm/m-Â°C	6.994 Âµin/in-Â°F
-	@Temperature 25.0 - 200 Â°C	@Temperature 77.0 - 392 Â°F
	13.33 Âµm/m-Â°C	7.406 Âµin/in-Â°F
	@Temperature 25.0 - 400 Â°C	@Temperature 77.0 - 752 Â°F
	14.27 Âµm/m-Â°C	7.928 Âµin/in-Â°F
	@Temperature 25.0 - 700 Â°C	@Temperature 77.0 - 1290 Â°F
Transformation Temperature	785 Â°C	1450 Â°F
Component Elements Properties	**Metric**	**English**
Carbon, C	0.50%	0.50%
Chromium, Cr	3.25%	3.25%
Iron, Fe	93.85%	93.85%
Manganese, Mn	0.70%	0.70%
Molybdenum, Mo	1.40%	1.40%
Silicon, Si	0.30%	0.30%

2.7 EN 8

Mechanical Properties

Heat Treatment	Tensile Strength Rm	Yield Strength Rm	Rp 0.2	A min on	Impact		Hardness
				$5.65\sqrt{So}$	Izod Ft.lb	KCV J	
	MPa	MPa	MPa				HB
N	550	280	–	16	15	16	152/207
	510	245	–	17	–	–	146/197
Q	625/775	385	355	16	25	28	179/229
R	700/850	465	450	16	25	28	201/255

2.8 P20 Steel

Physical Properties	Metric	English	
Density	7.85 g/cc	0.284 lb/inÂ^{3}	
Mechanical Properties	**Metric**	**English**	**Comments**
Hardness, Brinell	300	300	
Hardness, Rockwell C	30	30	Typical
Tensile Strength, Ultimate	965 - 1030 MPa	140000 - 150000 psi	
Tensile Strength, Yield	827 - 862 MPa	120000 - 125000 psi	
Elongation at Break	20%	20%	in 50 mm (2")
Modulus of Elasticity	205 GPa	29700 ksi	
Compressive Strength	862 MPa	125000 psi	
Charpy Impact	27.1 - 33.9 J	20.0 - 25.0 ft-lb	V-Notch
Thermal Properties	**Metric**	**English**	**Comments**
CTE, linear	12.8 Âµm/m-Â°C	7.10 Âµin/in-Â°F	
	@Temperature 20.0 Â°C	@Temperature 68.0 Â°F	
Thermal Conductivity	29.0 - 34.0 W/m-K	201 - 236 BTU-in/hr-ftÂ^{2}-Â°F	
Component Elements Properties	**Metric**	**English**	**Comments**
Carbon, C	0.28 - 0.40 %	0.28 - 0.40 %	
Chromium, Cr	1.4 - 2.0 %	1.4 - 2.0 %	
Iron, Fe	97%	97%	As remainder
Manganese, Mn	0.60 - 1.0 %	0.60 - 1.0 %	
Molybdenum, Mo	0.30 - 0.55 %	0.30 - 0.55 %	
Phosphorus, P	<= 0.030 %	<= 0.030 %	
Silicon, Si	0.20 - 0.80 %	0.20 - 0.80 %	
Sulfur, S	<= 0.030 %	<= 0.030 %	

2.9 2378 Alloy

C(%)	Si(%)	Mn(%)	P(%)	S(%)	Cr(%)	Ni(%)	Mo(%)	N(%)	Cu(%)
Max 0.020	Max 0.80	Max 1.0	Max 0.03	Max 0.01	19.5-20.5	17.5-18.5	6.0-6.5	0.18-0.22	0.50-1.0
Proof strength	Tensile strength	Impact energy	Elongation at fracture	Reduction in cross section on fracture	As-Heat-Treated Condition	Brinell hardness(HBW)			
***R*p0.2(MPa)**	*R*m(MPa)	KV(J)	*A*(%)	*Z*(%)					
343(≥)	874(≥)	34	13	12	Solution and Aging,Annealing, Ausaging ,Q+T,etc	221			

Property	Density	Temperature T	Specific heat	Thermal conductivity	Electric resistance	Modulus of elasticity	Expansion rate	
	kg/dm3	°C/F	J/kgK	W/mK	μΩ·cm	kN/mm2		
457(≥)	257(≥)	23	24	22	Solution and Aging,Annealing, Ausaging ,Q+T,etc	321		
Temp.	Creep strain limit	Creep rupture strength						
°C/°F	(10000h)	(10000h)						
	(Rp1,0)N/mm2	(Rp1,0) N/mm2						
662	157	352						

3.0 LITERATURE REVIEW

Sreeharan, B. N., said in his document titled *"DEAR – Data Envelopment Analysis based Ranking using MS EXCEL"* he introduces the DEAR (Data Envelopment Analysis based Ranking) method, a decision-making tool derived from Data Envelopment Analysis (DEA). DEA was originally proposed by Charnes et al. in 1978. DEAR simplifies the multi-criteria decision-making by eliminating the need for subjective weight assignments and instead uses a Multi-Response Performance Index (MRPI) to rank alternatives. In his overview, he maps original responses into MRPI, a ratio used to evaluate and rank alternatives. It is particularly useful for selecting the best alternative among multiple viable options without predefined weights.

Procedure for DEAR:
The method involves the following steps:

Step 1: Frame an alternate and objective matrix (O_{ij}), where rows represent alternatives and columns represent objectives.

Step 2: Compute normalized values (N_{ij}) using:

For maximization:

$$N_{ij} = \frac{O_{ij}}{\sum_{i=1}^{ns} O_{ij}}$$

For minimization:

$$N_{ij} = \frac{\frac{1}{O_{ij}}}{\sum_{i=1}^{ns} \frac{1}{O_{ij}}}$$

Step 3: Calculate the weighted response matrix (A_{ij}) as:

$$A_{ij} = N_{ij} * O_{ij}$$

Step 4: Determine the MRPI ratio (R_i) by dividing the sum of maximum objective weighted responses (W_{mxi}) by the sum of minimum objective weighted responses (W_{mmi}):

$$MRPI(R_i) = \frac{W_{mxi}}{W_{mmi}}$$

Where,

$$W_{mxi} = \sum_{j=1}^{max} A_{ij}$$

$$W_{mmi} = \sum_{J=1}^{mix} A_{ij}$$

Step 5: Rank alternatives based on MRPI values, with the highest-ranked alternative (Rank 1) being the best choice.

4.0 RESULTS AND DISSCUSSION

These are the values and results that are obtained in excel

Constructing the Alternate-Objective Matrix (O_{ij})

Purpose: To organize raw data for evaluation.

Structure:

Rows: 9 mold materials (e.g., EN 8, P 20, 718 Alloy,etc,.).

Columns: 13 objectives (e.g., Tensile Strength, Corrosion Resistance, Tool Life,etc,.).

Example:

For **EN 8**, Tensile Strength = 700 MPa (max value from range in Sheet1).

For **4140 Alloy Steel**, Yield Strength = 65 MPa (minimization objective, so lowest value is used).

`	EN 8	P 20	H 13 TOOL STEEL	718 Alloy	718 H	2378 Alloy	NAK80 Tool Steel	4140 Alloy Steel	S7 Alloy steel	Sum	
Tensile Strength (Mpa)	700	1000	1500	1350	1200	2200	1400	950	2070	12370	Max
Yield Strength (Mpa)	400	800	1200	1170	1000	2000	1200	65	1650	9485	Max
Impact Strength J	40	50	60	150	60	20	30	30	81	521	Max
Elongation	20	20	12	20	20	10	20	20	15	157	Max
Modulus of Elasticity (Gpa)	210	205	210	200	210	210	210	205	210	1870	Max
Thermal Conductivity W/m-K	51.9	29	30	16.3	30	25	30	42.6	24.9	279.7	Max
Hardening Temperature (^{0}C)	860	870	1050	980	870	1050	550	870	980	8080	Max
Machinability Index	3	4	2	1	3	2	3	3	3	24	Max
Corrosion Resistance	1	3	4	5	3	3	3	2	2	26	Max
Wear Resistance	2	3	4	3	3	4	4	3	4	30	Max
Tool Life	1	2	3	2	2	2	2	2	3	19	Max
Toughness	2	3	3	3	2	1	2	2	3	21	Max
Hardness (HRC)	30	32	55	45	38	62	43	32	61	398	Min
Oij											

Step 2: Normalization of Values (Nij)

Purpose: Standardize disparate units/scales for fair comparison.

Methods:

Maximization Objectives (e.g., Tensile Strength, Tool Life):

$$N_{ij} = \frac{O_{ij}}{\sum_{i=1}^{ns} O_{ij}}$$

Example: Normalized Tensile Strength for **EN 8** = 700 / (700+1000+...+2070).

Minimization Objectives (e.g., Hardening Temperature):

$$N_{ij} = \frac{\frac{1}{O_{ij}}}{\sum_{i=1}^{ns} \frac{1}{O_{ij}}}$$

Example: Normalized Hardening Temp for **H 13 Tool Steel** = (1/1050) / (1/860 + 1/870 + ... + 1/980).

Implementation in Sheet2:

From the columns **B15:M23** from excel the normalized values for each objective is calculated.

Hardness (HRC) is treated as a minimization objective (lower hardness may be preferred for machinability).

	Tensile Strength (Mpa)	Yield Strength (Mpa)	Impact Strength J	Elongation	Modulus of Elasticity (Gpa)
EN 8	0.056588521	0.04217185	0.076775432	0.127388535	0.112299465
P 20	0.080840744	0.084343701	0.09596929	0.127388535	0.109625668
H 13 TOOL STEEL	0.121261116	0.126515551	0.115163148	0.076433121	0.112299465
718 Alloy	0.109135004	0.123352662	0.287907869	0.127388535	0.106951872
718H	0.097008892	0.105429626	0.115163148	0.127388535	0.112299465
2378 Alloy	0.177849636	0.210859251	0.038387716	0.063694268	0.112299465
NAK80 Tool Steel	0.113177041	0.126515551	0.057581574	0.127388535	0.112299465
4140 Alloy Steel	0.076798707	0.006852926	0.057581574	0.127388535	0.109625668
S7 Alloy steel	0.16734034	0.173958882	0.15547025	0.095541401	0.112299465

Thermal Conductivity W/m-K	Hardening Temperature (0C)	Machinability Index	Corrosion Resistance	Wear Resistance
0.185555953	0.106435644	0.125	0.038461538	0.066666667
0.103682517	0.107673267	0.166666667	0.115384615	0.1
0.107257776	0.129950495	0.083333333	0.153846154	0.133333333
0.058276725	0.121287129	0.041666667	0.192307692	0.1
0.107257776	0.107673267	0.125	0.115384615	0.1
0.08938148	0.129950495	0.083333333	0.115384615	0.133333333
0.107257776	0.068069307	0.125	0.115384615	0.133333333
0.152306042	0.107673267	0.125	0.076923077	0.1
0.089023954	0.121287129	0.125	0.076923077	0.133333333

Tool Life	Toughness	Nij Max	
0.0526316	0.0952381	-	-
0.1052632	0.1428571	-	-
0.1578947	0.1428571	-	-
0.1052632	0.1428571	-	-
0.1052632	0.0952381	-	-
0.1052632	0.047619	-	-
0.1052632	0.0952381	-	-
0.1052632	0.0952381	-	-
0.1578947	0.1428571	-	-

Step 3: Weighted Response Matrix (Aij)

Purpose: Combine normalized importance and raw performance.

Formula:

$$A_{ij} = N_{ij} * O_{ij}$$

Example:

For **P 20**, Weighted Tensile Strength = Nij (from B16) × 1000 MPa.

Implementation:

Columns **B49:M57** compute weighted responses for each material.

	Hardness (HRC)	1/Oij
EN 8	0.033333333	-
P 20	0.03125	-
H 13 TOOL STEEL	0.018181818	-
718 Alloy	0.022222222	-
718H	0.026315789	-
2378 Alloy	0.016129032	-
NAK80 Tool Steel	0.023255814	-
4140 Alloy Steel	0.03125	-
S7 Alloy steel	0.016393443	-
	0.218331452	-

	Hardness (HRC)	Nij - Min
EN 8	0.152673071	-
P 20	0.143131004	-
H 13 TOOL STEEL	0.083276221	-
718 Alloy	0.101782047	-
718H	0.120531372	-
2378 Alloy	0.073874067	-
NAK80 Tool Steel	0.106516096	-
4140 Alloy Steel	0.143131004	-
S7 Alloy steel	0.075085117	-

Step 4: Multi-Response Performance Index (MRPI)

Purpose: Total performance into a single rankable metric.

Formula:

MRPI=Sum of Maximization Objectives (Wmxi)Sum of Minimization Objectives (Wmmi)*MRPI*=Sum of Minimization Objective s (Wmmi)Sum of Maximization Objectives (Wmxi)

Wmxi: Sum of weighted responses for objectives to **maximize** (e.g., Tensile Strength, Toughness).

Wmmi: Sum of weighted responses for objectives to **minimize** (e.g., Hardening Temperature).

Example:

For **718 Alloy**, MRPI = (Sum of B52:M52) / N52 (where N52 is the weighted Hardness value).

Implementation:

Column **B60:B68** calculates MRPI for each material.

	Tensile Strength (Mpa)	Yield Strength (Mpa)	Impact Strength J	Elongation
EN 8	39.61196443	16.86874012	3.071017274	2.547770701
P 20	80.84074373	67.47496046	4.798464491	2.547770701
H 13 TOOL STEEL	181.8916734	151.818661	6.909788868	0.917197452
718 Alloy	147.3322555	144.3226147	43.18618042	2.547770701
718H	116.410671	105.4296257	6.909788868	2.547770701
2378 Alloy	391.2691997	421.7185029	0.767754319	0.636942675
NAK80 Tool Steel	158.4478577	151.818661	1.727447217	2.547770701
4140 Alloy Steel	72.95877122	0.445440169	1.727447217	2.547770701
S7 Alloy steel	346.3945028	287.032156	12.59309021	1.433121019

Modulus of Elasticity (Gpa)	Thermal Conductivity W/m-K	Hardening Temperature (0C)	Machinability Index	Corrosion Resistance
23.5828877	9.630353951	91.53465347	0.375	0.038461538
22.47326203	3.006792992	93.67574257	0.666666667	0.346153846
23.5828877	3.217733286	136.4480198	0.166666667	0.615384615
21.39037433	0.949910619	118.8613861	0.041666667	0.961538462
23.5828877	3.217733286	93.67574257	0.375	0.346153846
23.5828877	2.234537004	136.4480198	0.166666667	0.346153846
23.5828877	3.217733286	37.43811881	0.375	0.346153846
22.47326203	6.488237397	93.67574257	0.375	0.153846154
23.5828877	2.21669646	118.8613861	0.375	0.153846154

Wear Resistance	Tool Life	Toughness	Hardness (HRC)	Aij
0.133333333	0.0526316	0.1904762	4.580192137	-
0.3	0.2105263	0.4285714	4.580192137	-
0.533333333	0.4736842	0.4285714	4.580192137	-
0.3	0.2105263	0.4285714	4.580192137	-
0.3	0.2105263	0.1904762	4.580192137	-
0.533333333	0.2105263	0.047619	4.580192137	-
0.533333333	0.2105263	0.1904762	4.580192137	-
0.3	0.2105263	0.1904762	4.580192137	-
0.533333333	0.4736842	0.4285714	4.580192137	-

Step 5: Ranking

Purpose: Identify the best-performing material.

Method:

Materials are ranked in descending order of MRPI (higher MRPI = better performance).

Excel's RANK() function is used in Column **C60:C68**.

	MRPI	**Rank**
EN 8	40.96712204	9
P 20	60.42752071	7
H 13 TOOL STEEL	110.6948326	3
718 Alloy	104.9154229	4
718H	77.11387767	6
2378 Alloy	213.5198948	1
NAK80 Tool Steel	83.0611369	5
4140 Alloy Steel	44.00394436	8
S7 Alloy steel	173.3722629	2

5.0 CONCLUSION

From the above method and research we can conclude that **2378 Alloy** gets the 1st rank, this is the suitable material for the mold that is involved in the injection moulding process. Overall, the DEAR method gave me a structured way to compare different alternatives and make a logical choice based on objective data.

REFRENCES

[1] Sreeharan, B. N. (2021). *DEAR – Data Envelopment Analysis based Ranking using MS EXCEL*. Kumaraguru College of Technology.

[2] Material Properties from MatWeb.