Multi objective optimization of WEDM parameters for low-carbon mold steel

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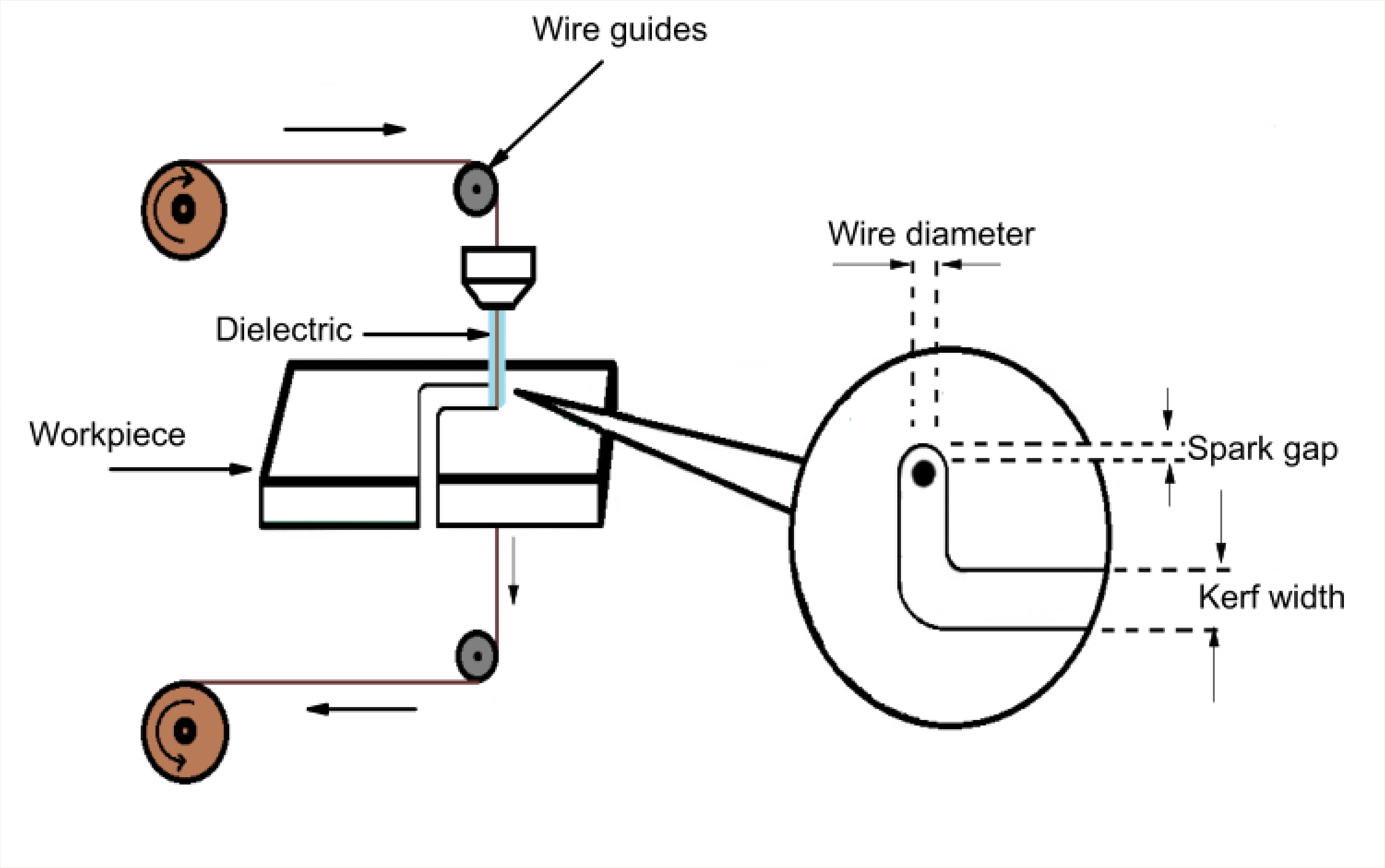
Introduction

Wire-EDM



AISI P20 tool steel

Defining property	AISI-SAE grade	Significant characteristics
Water-hardening	W	
Cold-working	O	Oil-hardening
	A	Air-hardening; medium alloy
	D	High carbon; high chromium
Shock resisting	S	
High speed	T	Tungsten base
	M	Molybdenum base
Hot-working	H	H1–H19: chromium base H20–H39: tungsten base H40–H59: molybdenum base
Plastic mold	P	
Special purpose	L	Low alloy
	F	Carbon tungsten

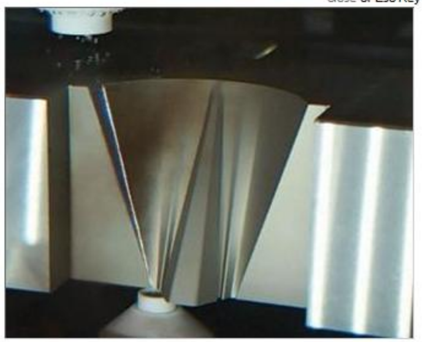
Composition of AISI P20 tool steel

Element	Content (%)
C	0.28-0.40
Mn	0.60-1.00
Si	0.20-0.80
Cr	1.40-2.00
Mo	0.30-0.55
Cu	0.25
P	0.03
S	0.03

Note: 1% Nickel is added for more hardness

Applications

China OEM plastic injection mould parts and High speed CNC milling , Wire cut EDM process Manufacturer



This injection mold was machined on a wire EDM using soft brass wire and tapering up to 30 degrees. The machine uses optional large-opening flush nozzles that prevent the wire from curling over the opening of the nozzle during the machining of the large taper sections.

Services

Plastic Injection Molds

Mold Repair and Engineering Changes

Specialty Machining

Jigs and Fixtures

Plastic Injection Molds

At TST we design and build single and multi-cavity molds ranging from small MUD insert molds to self-contained molds up to 24" x 36" in size and weighing up to 2 tons.

Most molds are conventional in type with slides, collapsible cores and so forth. We do have experience in building more complicated tooling which includes Hot Runner Molds, Unscrewing molds, 3 plate molds, stripper plate and floating plate type molds.

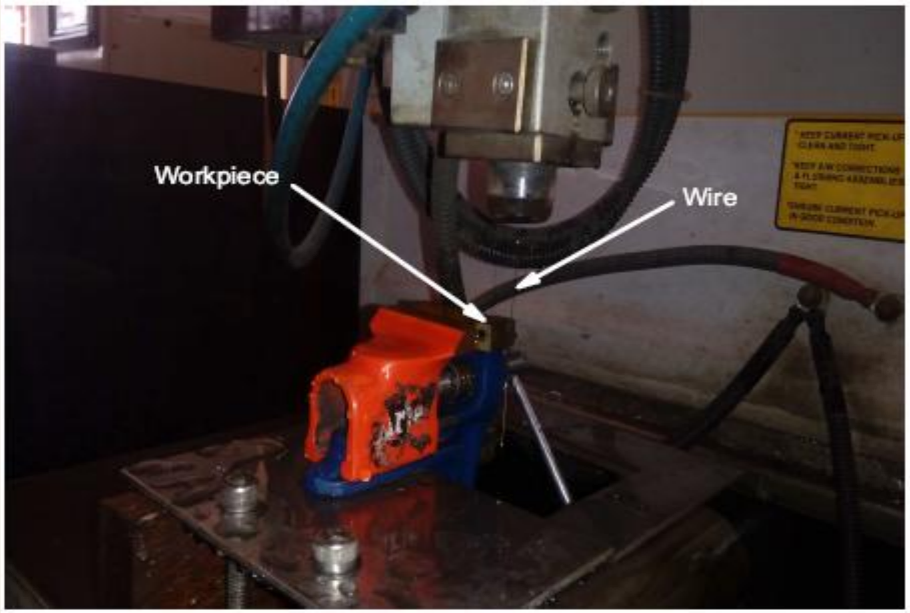
We meet SPI Industry guidelines in our mold building and we build molds ranging from class 101 classification on down depending on and meeting our customer needs.

We utilize Solidworks 2012 for our mold designs and Mastercam X6 for our CNC programming of our cores, cavities, detailed work and all mold base machining. We utilize our CNC capabilities with both of our Haas CNC Mills, Mitsubishi Wire EDM and our Charmilles Roboform EDM Sinker.

Experimental details

Controlling parameters with levels

Parameters	Levels		
	1	2	3
Pulse-on-time [μs]	100	110	120
Pulse-off-time [μs]	3	23	43
Servo voltage [V]	20	40	60



Grey relational analysis

Algorithm of grey relational analysis

Normalizing the experimental results of MRR and KW for all experimental runs.

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Calculating the grey relational coefficients (GRC).

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Calculating the grey relational grade (GRG) by averaging the GRCs.

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Performing statistical analysis of variance (ANOVA) for the input parameters with the GRG to determine the significant parameters affecting the process.

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Selecting the optimal levels of process parameters

Data preprocessing :

- lower is better

$$x_i^*(k) = \frac{x_i^k - min x_i^k}{max x_i^k - min x_i^k}$$

- higher is better

$$x_i^*(k) = \frac{\max x_i^k - x_i^k}{max x_i^k - min x_i^k}$$

- Nominal the best

$$x_i^*(k) = \frac{1 - |X_i(K) - X_0\, b(k)|}{max\ x_i^k - X_0 b(k)}$$

Grey relational coefficients (GRC) :

$$\gamma_i(k) = \gamma(x_0(k)) = \frac{\Delta \min + \xi \Delta max}{\Delta_{0,i}(k) + \xi \Delta max}$$

i=1; . . . ; n; k= 1; . . . ; p

where, $\Delta_{0,i}(k)$ = $|x_0(k) - x_i(k)|$ is the difference of the absolute value called deviation sequence of the reference sequence $x_0(k)$ and comparability $x_i(k)$. The ζ is the distinguishing coefficient or identification coefficient $0 \leq \zeta \leq 1$. In general, it is set to 0.5.

Grey relational grade (GRG) :

weighing-sum of the grey relational coefficients

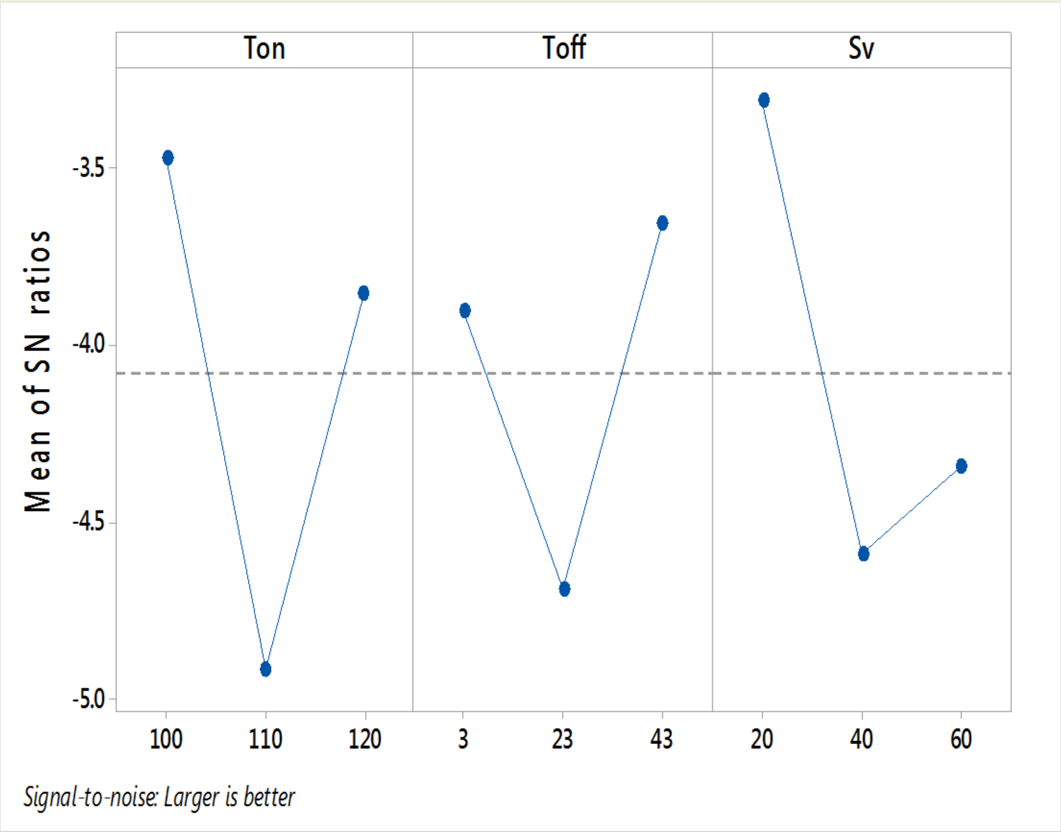
$\gamma (x_0, x_i) = \sum_n^{k=1} \beta_k (x_0 , x_i)$

Results

L9 orthogonal array with responses

Sl. No.	Ton	Toff	Sv	Nor MRR	Nor KW	GRC ζi (mrr)	GRC ζi (Kw)	GRG
1	100	3	20	0.000	1.000	0.333	1.000	0.706
2	100	23	40	0.489	0.768	0.495	0.683	0.649
3	100	43	60	0.219	0.928	0.390	0.875	0.658
4	110	3	40	0.375	0.673	0.444	0.266	0.526
5	110	23	60	0.625	0.725	0.571	0.645	0.485
6	110	43	20	0.489	0.768	0.495	0.683	0.717
7	120	3	60	0.645	0.254	0.585	0.401	0.699
8	120	23	20	1.000	0.106	1.000	0.359	0.629
9	120	43	40	0.781	0.000	0.696	0.766	0.600

Main effects plot for GRG



Response Table for Means

Level	Ton	Toff	Sv
1	0.6710	0.6437	0.6840
2	0.5760	0.5877	0.5917
3	0.6427	0.6583	0.6140
Delta	0.0950	0.0707	0.0923
Rank	1	3	2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% contribution
Ton	2	0.014272	0.007136	0.92	0.02	0.39
Toff	2	0.008345	0.004172	0.54	0.06	0.23
Sv	2	0.013924	0.006962	0.9	0.526	0.38
Error	2	0.015452	0.007726			
Total	8	0.051993				

Regression Equation

GRG = 0.6299 + 0.0411 Ton_100 - 0.0539 Ton_110 + 0.0128 Ton_120 + 0.0138 Toff_3 - 0.0422 Toff_23 + 0.0284 Toff_43 + 0.0541 Sv_20 - 0.0382 Sv_40 - 0.0159 Sv_60

Confirmatory experiment

Responses	Initial data $Ton_1Toff_1Sv_1$	Optimal machining parameter $Ton_1Toff_3Sv_1$	
		Experimental values	Predicted values
MRR (normalized)	0.00	0.200	
KW (normalized)	1.00	0.929	
GRG	0.706	0.761	0.757

Conclusion

The optimum setting to attain maximum GRG (minimum KW with maximum MRR) :

Ton of 100 µs, Toff of 43 µs and Sv of 20 V.

Thank you…