# Optimisation of electrical discharge drilling using a natural analogue algorithm with nested strategy types

**E. Uhlmann[1,2], M. Polte[1,2], J. Streckenbach[1], M. Osmanovic[1], J. Börnstein[2]**

[1] Institute for Machine Tools and Factory Management IWF, Technische Universität Berlin, Germany
[2] Fraunhofer Institute for Production Systems and Design Technology IPK, Germany

## Introduction

- Aerospace industry as well as mould and tool making require high economic efficiency, combined with the corresponding high quality demands
- This motivates the necessity of finding suitable parameter combinations for the process of electrical discharge machining (EDM), e.g. when introducing new materials
- One promising method is the stochastic optimisation procedure evolution strategy (ES)
- Due to its metaheuristic approach, this optimisation method is excellently suited for very complex processes in which the interrelationship of the individual influencing variables is not known
- Using the example of drilling EDM, this work presents the results of the investigation on the suitability of the ES method
- Two nested ES-types were applied and compared
- The materials used were brass for the tool electrode and stainless steel X5CrNi18-1 for the workpiece electrode

## Applied evolution strategy

Description of the procedure:

- New parameters are generated as children of start or parent parameters by mutation and recombination
- New parameter sets are applied in real experiments
- Results obtained are evaluated with regard to the optimisation criterion
- Termination criteria for ES:
  - Specific objective function value
  - Fixed number of generations $\gamma_{max}$
  - Absence of significant improvements
- Target function for assessing improvement in terms of quality points $q_C$, with weighted target values erosion duration $t_{ero}$ and linear wear of tool electrode $\Delta l_E$:

$$q_c = 0.7 \cdot \frac{t_{ero}^{child}}{t_{ero}^{start}} + 0.3 \cdot \frac{\Delta l_E^{child}}{\Delta l_E^{start}}$$

- Elitist: the parents are included in selection
- Non-elitist: only children of current generation are included in the selection
- Functionality of nested ES-types:
  - After half of the performed generations the starting point for the following generation is determined by selecting the best children out of all previous generations
- The step size is reset to its initial value

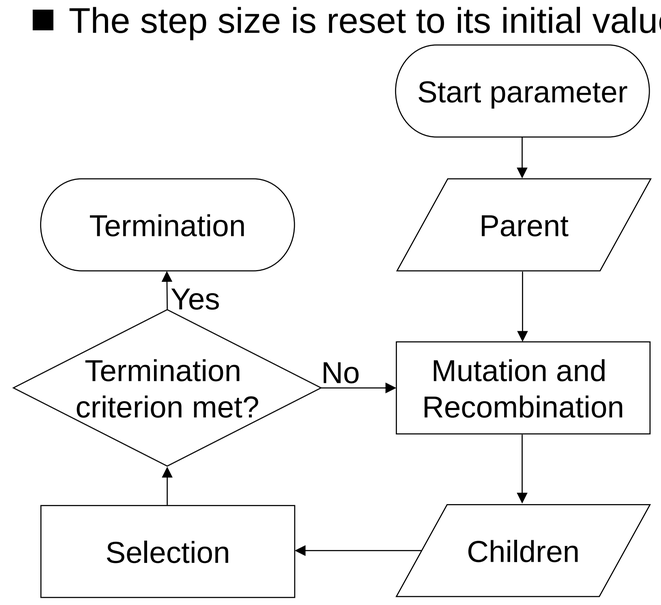
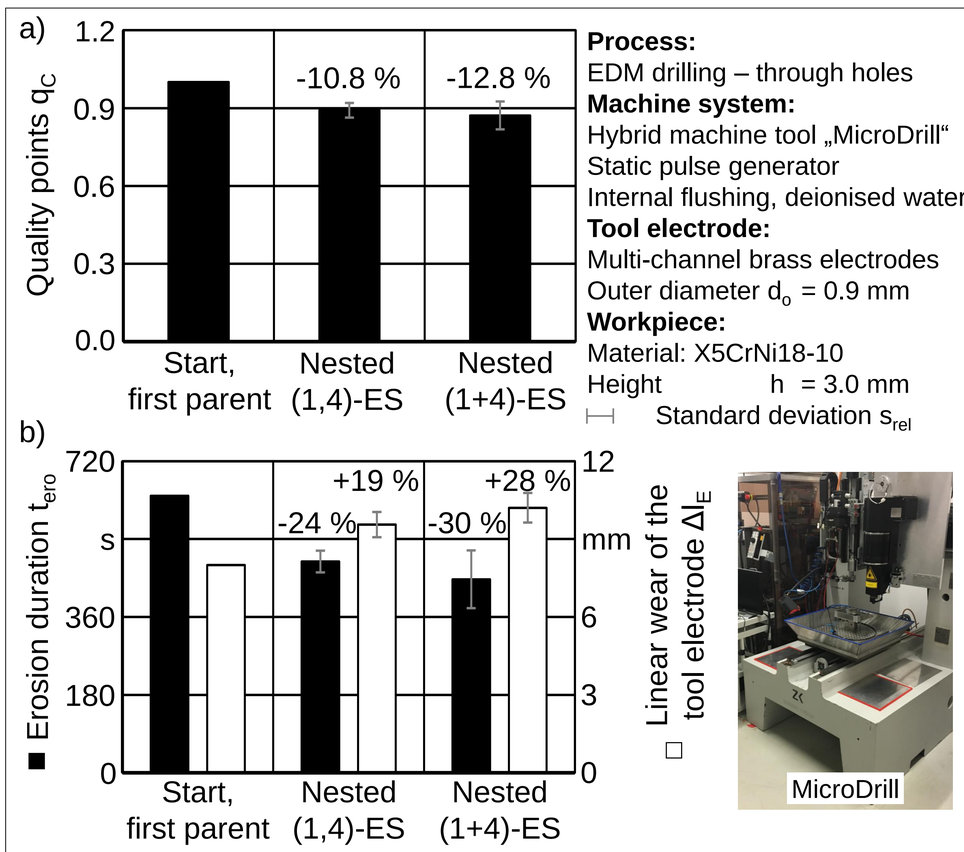



**Figure 1.** General procedure of the evolution strategy

## Investigation and results




**Process:**
EDM drilling – through holes
**Machine system:**
Hybrid machine tool „MicroDrill“
Static pulse generator
Internal flushing, deionised water
**Tool electrode:**
Multi-channel brass electrodes
Outer diameter $d_o$ = 0.9 mm
**Workpiece:**
Material: X5CrNi18-10
Height h = 3.0 mm
Standard deviation $s_{rel}$




**Figure 2.** Comparison before and after optimisation; a) quality points $q_C$; b) target values

- Two types of ES, a non-elitist nested (1,4)-ES and an elitist nested (1+4)-ES, with a number of parents of μ = 1 and a number of children of λ = 4 for each generation were applied
- Standard deviation $s_{rel}$ was calculated from the best three children out of three runs
- Improvements of the quality points $q_C$ by 10.8 % using the nested (1,4)-ES and 12.8 % using the nested (1+4)-ES were achieved
- Nested (1,4)-ES: erosion duration reduced by 24 % with $t_{ero}$ = 488 s, linear wear of the tool electrode $\Delta l_E$ increased by 19 % with $\Delta l_E$ = 9.55 mm
- Nested (1+4)-ES: erosion duration reduced by 30 % with $t_{ero}$ = 447 s, linear wear of the tool electrode $\Delta l_E$ increased by 28 % with $\Delta l_E$ = 10.20 mm
- The linear wear of the tool electrode $\Delta l_E$ is amplified due to the weighting in the calculation of the quality points $q_C$
- Optimisation of electrical discharge drilling is effectively possible using nested ES-types

**Table 1.** Comparison of parameters, quality points $q_C$ and target values before and after optimisation

| Technology | Discharge current $i_e$ | Open circuit voltage $\hat{u}_i$ | Discharge duration $t_e$ | Pulse interval time $t_0$ | Erosion duration $t_{ero}$ | Linear wear of the tool electrode $\Delta l_E$ | Quality points $q_C$ |
|---|---|---|---|---|---|---|---|
| **Start parameters** | 10.0 A | 180 V | 25 µs | 15 µs | 640 s | 8.00 mm | 1.000 |
| **Nested (1,4)-ES** | 11.9 A | 170 V | 23 µs | 15 µs | 481 s | 9.07 mm | 0.866 |
| **Nested (1+4)-ES** | 12.5 A | 182 V | 23 µs | 7 µs | 371 s | 10.76 mm | 0.809 |

## Conclusion

- Both algorithms of the nested ES show the potential to be used for the optimisation of EDM applications in the industry
- Nested (1+4)-ES results in best process improvements with reductions of the quality points $q_C$ by 12.8 % and erosion duration $t_{ero}$ by 30 %
- Due to the weighting of the target values, the linear wear of the tool electrode $\Delta l_E$ has increased
- With the weighting of the target values, it is possible to steer the optimisation in a certain direction
- Electrical discharge drilling can be optimised using the nested ES

INSTITUTE FOR MACHINE TOOLS AND FACTORY MANAGEMENT TECHNISCHE UNIVERSITÄT BERLIN

INSTITUTE PRODUCTION SYSTEMS AND DESIGN TECHNOLOGY

**Contact:**
Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann
Mirsad Osmanovic, M.Eng.
Tel.: +49-30 314-75305
E-Mail: osmanovic@iwf.tu-berlin.de