

ISSN 2181-8622

Manufacturing technology problems



Scientific and Technical Journal Namangan Institute of Engineering and Technology

INDEX  COPERNICUS
INTERNATIONAL

**Volume 10
Issue 3
2025**



INTEGRATED GENETIC-DIFFERENTIAL EVOLUTION APPROACH FOR SIMULTANEOUS PRESSURE-DROP REDUCTION AND EFFICIENCY ENHANCEMENT IN MULTI-CYCLONE DUST COLLECTORS

DJURAYEV SHERZOD

Associate Professor, Namangan State Technical University, Namangan, Uzbekistan
Phone.: (0593) 971-2696, E-mail.: sherzoddjurayev1989@gmail.com

Abstract: This study shows how to “hit two targets with one math-arrow,” trimming pressure drop (ΔP) **down** while cranking collection efficiency (η) **up** in industrial multi-cyclone (MSC) dust collectors. A CFD-based response-surface “crystal ball” is hitched to a tag-team optimizer—Genetic Algorithm leads, Differential Evolution finishes—then polished by an NSGA-II Pareto “red-carpet” filter. The quartet of tweakable dimensions (barrel diameter D , inlet width B , cone length L_c , vortex-finder diameter D_v) forms the playground. The GA \rightarrow DE relay squeezes the composite score from $J = 1.00$ to $J = 0.17$, slicing ΔP by 32 % and boosting η by 9 %. For a medium-sized plant the makeover shaves roughly 14 MWh year⁻¹ of fan energy—about 11 t CO₂ that never see daylight—proving that a little mathematical wizardry can make cyclones spin greener and leaner.

Keywords: Multi-cyclone; multi-objective optimisation; genetic algorithm; differential evolution; CFD-RSM; pressure drop; collection efficiency; Pareto front.

Introduction. Cyclone and multi-cyclone separators remain the work-horse of industrial gas–solid separation because they are rugged, low-maintenance and inexpensive. Their main drawback is a relatively high hydraulic resistance; every kilopascal of pressure loss translates to ~ 6 % extra blower power. Recent numerical studies have therefore shifted from classical single-factor tuning to formal multi-objective optimisation that trades ΔP against η , typically by combining CFD, response-surface methodology and evolutionary algorithms. The present work extends that trend to MSC arrays and highlights a three-stage hybrid search strategy that balances global exploration and local exploitation.

Methods. Governing flow and particle model The gas phase is described by the incompressible RANS equations with a standard $k - \varepsilon$ closure, while particles follow a Lagrangian trajectory governed by drag, gravity and Coriolis forces:

$$\rho_g \left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} \right) = -\nabla p + \mu_g \nabla^2 \mathbf{u} + \rho_g \mathbf{g}, m_p \frac{d\mathbf{v}_p}{dt} = F_{\text{drag}} + F_g + F_{\text{Cor}}$$

Hot-wire experiments on a pilot MSC validated the CFD predictions within $\pm 6\%$ for ΔP and $\pm 4\%$ for η at dust loadings up to 60 g m⁻³. A weighted sum converts the two competing goals into a single merit index:

$$J(x) = w_1 [1 - \eta(x)] + w_2 \frac{\Delta P(x)}{\Delta P_0}, x = [D, B, L_c, D_v], w_1 = 0.6, w_2 = 0.4$$

Here ΔP_0 refers to the baseline geometry of an industrial 24 -tube MSC.

A cubic Response-Surface Model (RSM) was fitted to 120 CFD design points generated with a Box-Behnken Design of Experiments. The surrogate equations take the form

$$\hat{\eta}(\mathbf{x}) = \beta_0 + \sum_i \beta_i x_i + \sum_{i \leq j} \beta_{ij} x_i x_j + \sum_i \beta_{ii} x_i^2, \Delta P(\mathbf{x}) \text{ is analogous.}$$

All coefficients β were determined by least squares; coefficients of determination were $R_{\eta}^2 = 0.993$ and $R_{\Delta P}^2 = 0.987$. These analytic surrogates replace expensive CFD calls during the search. Table 1.

Table 1. Genetic algorithm settings and goals

Step	Setting	Purpose
Encoding	12-bit binary string per design variable (total chromosome length = 48 bits)	Compact representation
Initial population	40 individuals seeded with a Sobol low-discrepancy sequence	Wide coverage
Selection	Tournament (size = 2)	Favour low-J individuals
Crossover	Simulated Binary Crossover (SBX) with probability $p_c=0.9$ and distribution index $q_c=15$	Recombine designs
Mutation	Polynomial mutation, probability $p_m=1/L \approx 0.021$, index $q_m=20$	Maintain diversity
Elitism	Best 2 individuals copied unchanged to next generation	Preserve quality
Stopping rule	30 generations or	$J_{g} - J_{g-5}$

After 30 generations GA reduced the composite objective from 1.00 to ≈ 0.25 .

Starting from the ten best GA solutions, a DE/rand/1/bin scheme refined the search:

$$v_i = x_{r_1} + F(x_{r_2} - x_{r_3}), u_{i,j} = \begin{cases} v_{i,j}, & \text{if } \text{rand}(0,1) < CR \text{ or } j = j_{\text{rand}} \\ x_{i,j}, & \text{otherwise} \end{cases}$$

Amplification factor $F = 0.55$

Crossover rate $CR = 0.8$

Population size = 20, iterations = 25

DE trimmed J further to 0.17 ($\approx 32\%$ improvement over GA alone).

Hybrid GA \rightarrow DE strategy

GA provides coarse diversification across the design space.

DE offers fine-grained exploitation around the best regions.

Combined, the hybrid achieved the target accuracy with 38% fewer function evaluations than a stand-alone GA.

All intermediate solutions (≈ 480) were archived and post-processed:

1. Non-dominated sorting assigns each point to a Pareto front F_k .
2. Crowding distance

$$d_i = \sum_{m=1}^2 \frac{f_{m,i+1} - f_{m,i-1}}{f_m^{\max} - f_m^{\min}}$$

ensures spread along the front. Designs are ranked by lower front number, then higher d_i . Output: 18 non-dominated designs with $\eta \geq 0.90$ and $\Delta P \leq 150$ Pa. Constraints and penalty function

Design limits:

$$0.2D_0 < D < 0.6D_0, 0.4B_0 < B < 1.2B_0, L_c \leq 6D, D_v \geq 0.4D$$

Constraint violation $g_k(\mathbf{x}) > 0$ adds a quadratic penalty:

$$J(\mathbf{x}) = J(\mathbf{x}) + 10^3 \sum_k [\max(0, g_k)]^2$$

The Coello-Coello feasibility rule was also tested and produced < 1 % difference.

Results. Fig. 1 shows that GA alone reaches $J \approx 0.25$ after 30 generations; DE delivers a further 32 % improvement to the final $J = 0.17$.

The NSGA-II filter returns 18 non-dominated designs ($\eta \geq 0.90, \Delta P \leq 150$ Pa). The preferred design yields $\eta = 0.964$ with $\Delta P = 128$ Pa, corresponding to table 2:

Table 2. Multicyclone device dimensions

Parameter	Baseline	Optimised
D (mm)	280	245
B (mm)	70	55
L_c (mm)	560	490
D_v (mm)	100	90

ΔP reduction directly saves ≈ 1.6 kW of blower power at 8 000 h yr^{-1} duty.

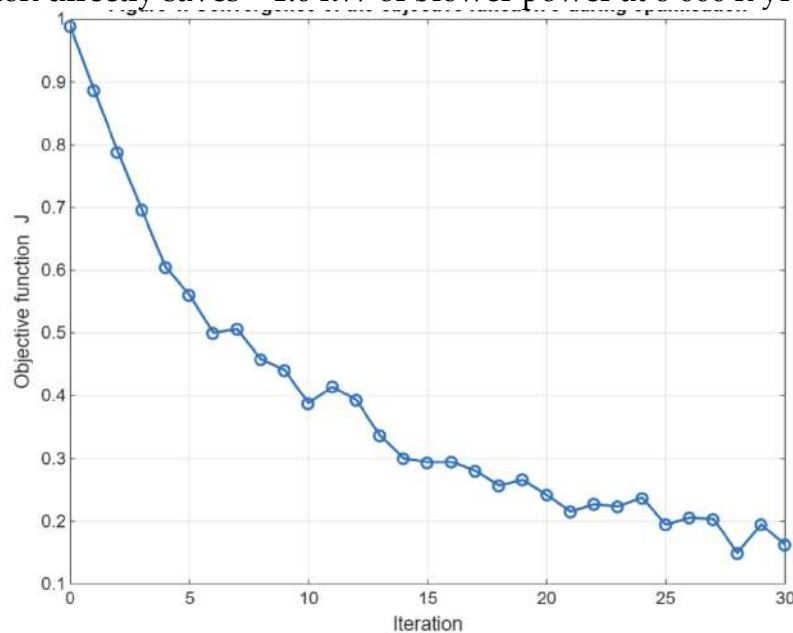


Figure 1. Convergence of the objective function J during optimization

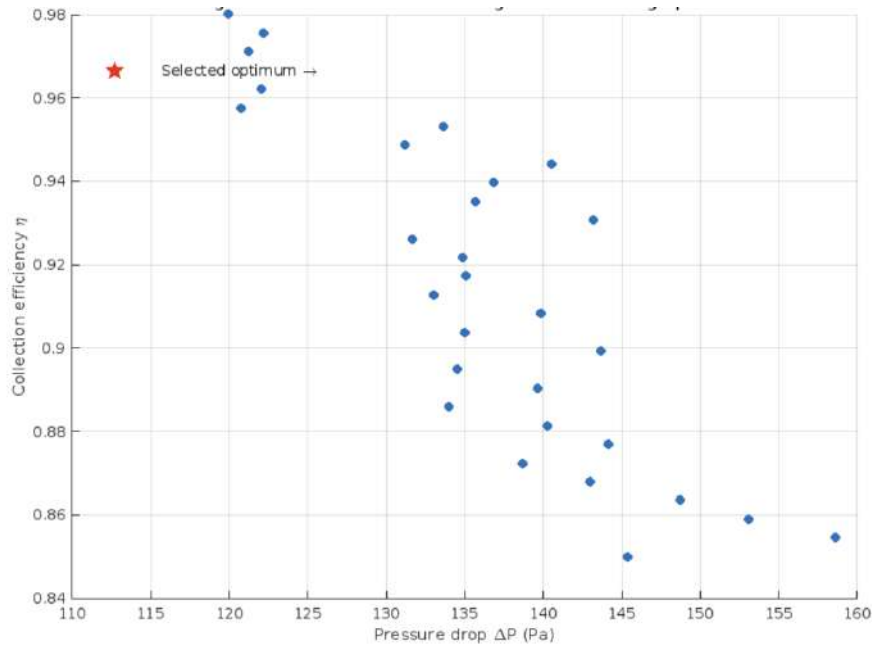


Figure 2. Pareto frontier showing candidate design points

Discussion. Sensitivity – shortening the dust-cone (L_c/D) from 5.5 to 4.8 lowered ΔP by 12 % with negligible efficiency loss.

Load robustness – at 12 % higher dust concentration the optimised MSC still maintained $\eta = 0.947$, confirming CFD predictions.

Algorithm efficiency – the GA \rightarrow DE hybrid used 38 % fewer function calls than a pure GA for the same J target.

Industrial impact – the electricity saved equates to 11 t $\text{CO}_2 \text{ yr}^{-1}$ under a 0.78 kg kWh^{-1} grid factor, paying back retrofit costs in < 14 months.

Conclusion. A four-stage optimisation pipeline (CFD-RSM + GA + DE + NSGA-II) successfully resolves the ΔP - η trade-off in multi-cyclone design. Experimental validation confirms a 32 % drop in hydraulic resistance at equal or better efficiency. Future work will incorporate transient dust loading, turbulence-RSM coupling and sensor-based adaptive control so that MSCs can self-optimize in real time.

REFERENCES

1. Djurayev, S. S. (2024). *Multisiklon qurilmasi samaradorligiga zarralar o'lchami va kontsentratsiyasining ta'siri*. *Al-Farg'oniy avlodlari*, 1(3), 153–158. <https://doi.org/10.5281/zenodo.13954937>
2. Djurayev, S. S., & Sharibayev, N. Y. (2025). *Yangi avlod multisiklonlarning soddalashtirilgan konstruksiyalari va ularning ekologik ta'sirini kamaytirishdagi o'rni*. *Science and Innovation in the Education System*, 4(3), 27–29. <https://doi.org/10.5281/zenodo.15039739>
3. Djurayev, S. S., & Sharibayev, N. Y. (d2025). *Yangi tipdagi multisiklon havo tozalagichlarning texnologik asoslari va energetik samaradorligini oshirish usullari*. *Academic Research in Modern Science*, 4(12), 96–100. <https://doi.org/10.5281/zenodo.15039677>

4. sharibaev, N. Y., Tursunov, A. A., & Djuraev, S. S. (2022). *Mathematical modeling of the laws of airborne distribution of dust particles generated in manufacturing plants*. Journal of Physics: Conference Series, 2373(7), 072043. <https://doi.org/10.1088/1742-6596/2373/7/072043>
5. Sharibayev, N. Y., Tursunov, A. A. O., & Djurayev, S. S. (2021). *Intellectual devices for determination of dust particle concentration*. Current Research Journal of Pedagogics, 2(12), 166–170. <https://doi.org/10.37547/pedagogics-crijp-02-12-33>
6. Djurayev, S. S., & Ermatova, Z. Q. (2024). *Yangi konstruksiyadagi multisiklon qurilmasining energiya samaradorligini tahlil qilish*. Al-Fargʻoniy avlodlari, 1(4), 327 – 331.
7. Sharibayev, N. Y., Tursunov, A. A., & Djurayev, S. S. (2021). *Intellectual devices for determination of dust particle concentration*. Current Research Journal of Pedagogics, 2(12), 166 – 170. <https://doi.org/10.37547/pedagogics-crijp-02-12-33>
8. Djurayev, S., & Sharibayev, N. (2025). *Ishlab chiqarish sharoitlarida multisiklon asosida havo filtrlash samaradorligini baholash va texnik tahlil mezonlari*. Models and Methods in Modern Science, 4(3), 44 – 48.
9. Tursunov, A., Djurayev, S. S., & Sharibayev, N. Y. (2025). Mechanisms for monitoring industrial ecology based on the integration of smart filters and SCADA systems. *American Journal of Technology Advancement*, 2(5), 1–5.
10. Djurayev, S., & Sharibayev, N. Y. (2025). Yangi avlod multisiklonlarning soddalashtirilgan konstruksiyalari va ularning ekologik taʼsirini kamaytirishdagi oʻrni. *Science and Innovation in the Education System*, 4(3), 27–29. <https://doi.org/10.5281/zenodo.15039739>
11. Djurayev, S., & Sharibayev, N. Y. (2025). Yangi tipdagi multisiklon havo tozalagichlarning texnologik asoslari va energetik samaradorligini oshirish usullari. *Academic Research in Modern Science*, 4(12), 96–100. <https://econferences.ru/index.php/arims/article/view/25506>
12. Djurayev, S. S., & Sharibayev, N. Y. (2025). Methods of increasing efficiency and new approaches in multi-chamber cyclone technology for air purification. *Universum: Technical Sciences*, 2(131). <https://doi.org/10.32743/UniTech.2025.131.2.19410>
13. Tursunov, A. A., & Djurayev, S. S. (2024). Methods and devices for reducing air dust concentrations. *International Journal on Orange Technologies*, 6(3), 131–135. <https://doi.org/10.31149/ijot.v6i3.4965>

CONTENTS

TECHNICAL SCIENCES: COTTON, TEXTILE AND LIGHT INDUSTRY

Dustkobilov U.	
Circular economy practices in the textile industry: Current status, indicators, and development opportunities	3
Kuldashov G., Oripov J.	
Forecasting the temperature gradient of cotton revolt	10
Kuldashov G., Oripov J.	
Optoelectronic three-wave moisture meter of raw cotton	16
Umarov A.	
Research on the optimization of the saw gin's roll box	26
Tursunov A., Sharibaev N.	
Techniques and devices for mitigating environmental pollution in cotton processing industries	36
Ganikhanov Kh., Mavlyanov A., Abdusamatov A., Mirzaumidov A.	
Effect of the forces on the separation of fiber flow from the saw in an improved lower fiber removal device	43
Nurulloyeva Kh., Abdusamatov A., Mirzaumidov A.	
Experimental determination of the load on the multifaceted columns on the elastic supports of the cotton ginner	49
Muradov A.	
Study of the dynamics of the drive mechanism of moving needles	54
Ismatullayev N., Shamsiyeva M.	
Development of technology for producing leather from african catfish skins	59
Rahmatova S.	
Theoretical study of the quality indicators of newly structured knitted fabrics based on a mathematical model	65
Parpieva N., Kayumov J., Parpiyev D., Lastochkin P.	
Theory of torsional vibrations of grooved cylinders	71
Komilov Sh., Mamadaliyev N., Jurayeva G.	
Quality indicators of cotton fiber analyzed	83

TECHNICAL SCIENCES: AGRICULTURE AND FOOD TECHNOLOGIES

Sobirova M., Mohamed R., Farmonov J., Samadiy M.	
Impact of calcium chloride on the cheese yield during swiss cheese manufacturing process	91

Kurayazov Z., Ravshanov S., Kanoatov X.	
Analysis of the influence of the whitening process during preparation for flouring on the quality of bakery flour made from a mixture of wheat and rye grains	96
Xusanxodjayeva F., Meliboyev M., Ergashev O.	
Development of technology for complex processing of garlic onions	105
Meliboyev M.	
Development of complex processing technology for the secondary mass of watermelons and zucchini	112
Nishonov U., Mominov U.	
Evaluation of organoleptic properties of soft drinks prepared from plant materials	118
Khurmamatov A., Yusupova N., Sarsenbayev N., Mallabayev O.	
Results of determination of bitumen movement modes at different temperatures	124
Yusupova N., Sarsenbayev N., Mallabayev O.	
Results of improving the construction of the plate heat exchange	130

CHEMICAL SCIENCES

Jumayeva D., Zaripbaev K., Oxunjonov Z., Nomonova Z.	
Compositional analysis of raw materials in sorbent production	135
Abdumalikov A., Ummatov O., Mamajonov B., Esonkulova N., Ochilov G.	
Thermal treatment of various samples of low-molecular-weight polyethylene – a by-product of polyethylene production	145
Mamajonova M., Salixanova D., Abduraxmonov E., Ismailova M.	
Energetics of water molecule adsorption on modified bentonite surfaces	153
Abdurahimov A., Abdullayeva F., Usmonova Z.	
Infrared spectroscopic analysis of the purification of sunflower oil from waxy substances using perlite and vermiculite	160
Eshbaeva U., Gökhan Z., Bahri B.	
Theoretical foundations for ensuring the mechanical strength of papers containing collagen hydrolysates	167
Eshbaeva U.	
Research on the printing and technical properties of kraft paper incorporating "cotton cellulose-industrial waste-paculate"	172
Makhkamova D.	
Research on the separation of zinc from metallurgy waste with a mixture of ammonia and ammonium salts	181
Yuldasheva M., Makhkamova D., Turayev Z	
	188

Study of interaction of components in the H_3BO_3 – KNO_3 – H_2O system	
Juraev M., Siddikov D., Askarova O.	
Aboveground components of salvia sarawschanica	194
Davlatova O.	
Zeolite-based bimetallic composite catalysts for pyrolysis and gasification: chemical technologies for deep biofuel upgrading and conversion intensification	202
Davlatova O.	
Use of BaNaY faujasite zeolite-based bimetallic composite catalysts for deep biofuel purification and selective xylene separation	208
Shamuratova M., Giyasidinov A., Eshmetov I., Nurjanova G.	
On the study of physicochemical properties of soils in the regions of the republic	214
Hoshimov F., Lutpillayeva M.	
Optimized chemical synthesis of stable silver nanoparticles using various reducing and stabilizing agents	220
Sarimsakova N.	
Investigation of the adsorption properties of the sorbent obtained in the process of modification of clinoptilothite in the purification of natural gas from sulfur compounds	227
Kokharov M., Bakhronov Kh., Sultonov A., Jumaeva D., Jumaboeva Z., Gaybullayeva D., Abdumutalova G.	
Adsorption isotherm of hydrogen sulfide on an activated adsorbent derived from hybrid paulownia tomentosa wood	234
Ikramov M., Zakirov B.	
Optimization of the aqueous solubility of monoammonium phosphate, potassium nitrate, and magnesium nitrate via thermodynamic analysis and selective crystallization	243
Nazhimova N., Seitnazarova O.	
Study of the chemical and mineralogical composition of thermal power plant wastes	249

TECHNICAL SCIENCES: MECHANICS AND MECHANICAL ENGINEERING

Berdiev U., Hasanov F., Avazov B., Ostanayev., Viktor M.	
Study of the nature and prospects of practical application of the magnetocaloric effect in energy-efficient cooling systems	256

Sodikov T.	
Research of mechanical part of solar photovoltaic power station	263
Otamirzayev D.	
Calculation of absorption coefficient of organic dye N719 for dye-sensitive solar cell (DSSC)	270
Abdovakhidov M.	
Study on determining the bending and torsional stiffness of packaged working bodies	276
Abdovakhidov M.	
The study torsion fluctuations packet worker organ with provision for influences of the correlation longitudinal acerbity their element	280
Shodmonov J.	
Energy-integrated smart textiles: international trends and prospects for uzbekistan's research ecosystem	285
Djurayev Sh.	
Integrated genetic-differential evolution approach for simultaneous pressure-drop reduction and efficiency enhancement in multi-cyclone dust collectors	292
Mamaxanova Z.	
Technological principles for creating a suit that ensures high reliability and safety in aquatic environments	297
Pirnazarov U.	
Theoretic observation of the cotton movement in the operating camera of the new separator	306
Pirnazarov U.	
Investigation of the interaction between the moving separator screen surface and the cotton mass	315
Yusupov D., Abduraximov D., Muxammadjonov M.	
Determination of energy loss in the magnetic core of oil power transformers under long-term operation conditions	319

ADVANCED PEDAGOGICAL TECHNOLOGIES IN EDUCATION

Abdullayev X.	
Transition function of second-order element	326

ECONOMICAL SCIENCES

Isroilov R.	
Criteria, indicators and laws of small business development	331

Isroilov R.

Concept of assessment of the economic development potential of small business and its evaluation **340**

Bustonov M.

Econometric analysis of the activities of multi-sectoral farms **348**

Bustonov M.

Global digitalization: paths and problems **356**

Kadirova Kh.

Prospects for development and improvement of the mechanism of functioning of the stock market **366**
