A project review

on

Multi Objective Optimization of Process Parameters for Friction welding using Genetic Algorithm

Under the guidance of

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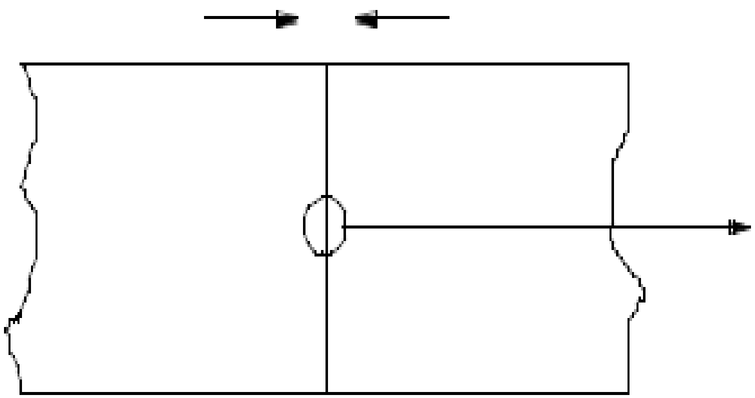
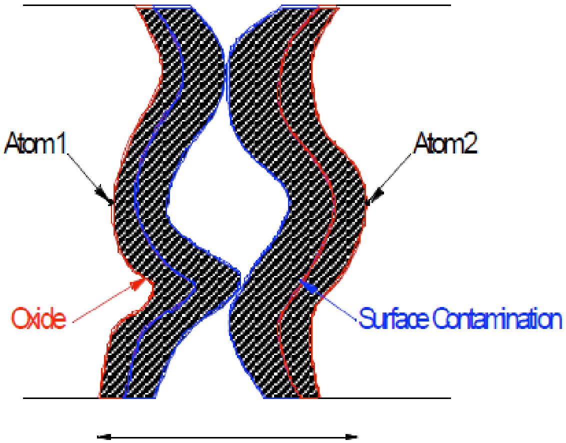
INTRODUCTION

Friction welding is a solid state joining process which can be used to join a number of different metals. Friction welding achieves 100 per cent metal-to-metal joints, giving parent metal properties. It is the only joining process to do this. No addition material or fillers are required and there are no emissions from the process.

- Two Polished Metal Surfaces Brought Into Contact.





Steps in friction welding process Cont'd…..,

(a) Pre friction
One part is held stationary In a fixed clamp. The other Part is held in a rotating Chuck.

(b) First friction
The chuck is accelerated to speed and parts brought in to contact.

(c) Second friction
The force is plastic material starts To extrude from the weld interface.

Cont'd….. ,

(d) Second friction
The second friction phase Continues until sufficient Material has been extruded.

(e) Forge
Rotation is stopped- the force increased and the Parts forged together.

(f) Weld complete
The weld is complete a full area, homogenous Bond.

Objectives in Multi-Objective Optimization

- **Two goals in a MOO**
  - To find a set as close as possible to the Pareto-optimal front
  - To find a set of solutions as diverse as possible

Difference with Single-Objective Optimization

- Two goals instead of one
- Dealing with two search space
  - objective space & decision space (for SOO)
- No artificial fix-ups
  - weight-sum, ε-constraints method

Concept of Domination

- A solution $x^{(1)}$ is said to dominate the other solution $x^{(2)}$, if both conditions 1 and 2 are true:
  - The solution $x^{(1)}$ is no worse that $x^{(2)}$ in all objectives
  - The solution $x^{(1)}$ is strictly better than $x^{(2)}$ in at least one objective

Evolutionary Algorithms

- Multi-modal-function optimization
  - ➢Multi-modal functions have multiple optimum solutions, of which many are local optimal solutions
  - ➢Diversity through mutation
  - ➢Pre-selection
  - ➢Crowding model
  - ➢Sharing function model
- Crowding & sharing function model are useful to MOEA

The Genetic Algorithm

- Directed search algorithms based on the mechanics of biological evolution
- Developed by John Holland, University of Michigan (1970's)
  - To understand the adaptive processes of natural systems
  - To design artificial systems software that retains the robustness of natural systems

Cont’d………,

- Provide efficient, effective techniques for optimization and machine learning applications
- Widely-used today in business, scientific and engineering circles

Components of a GA

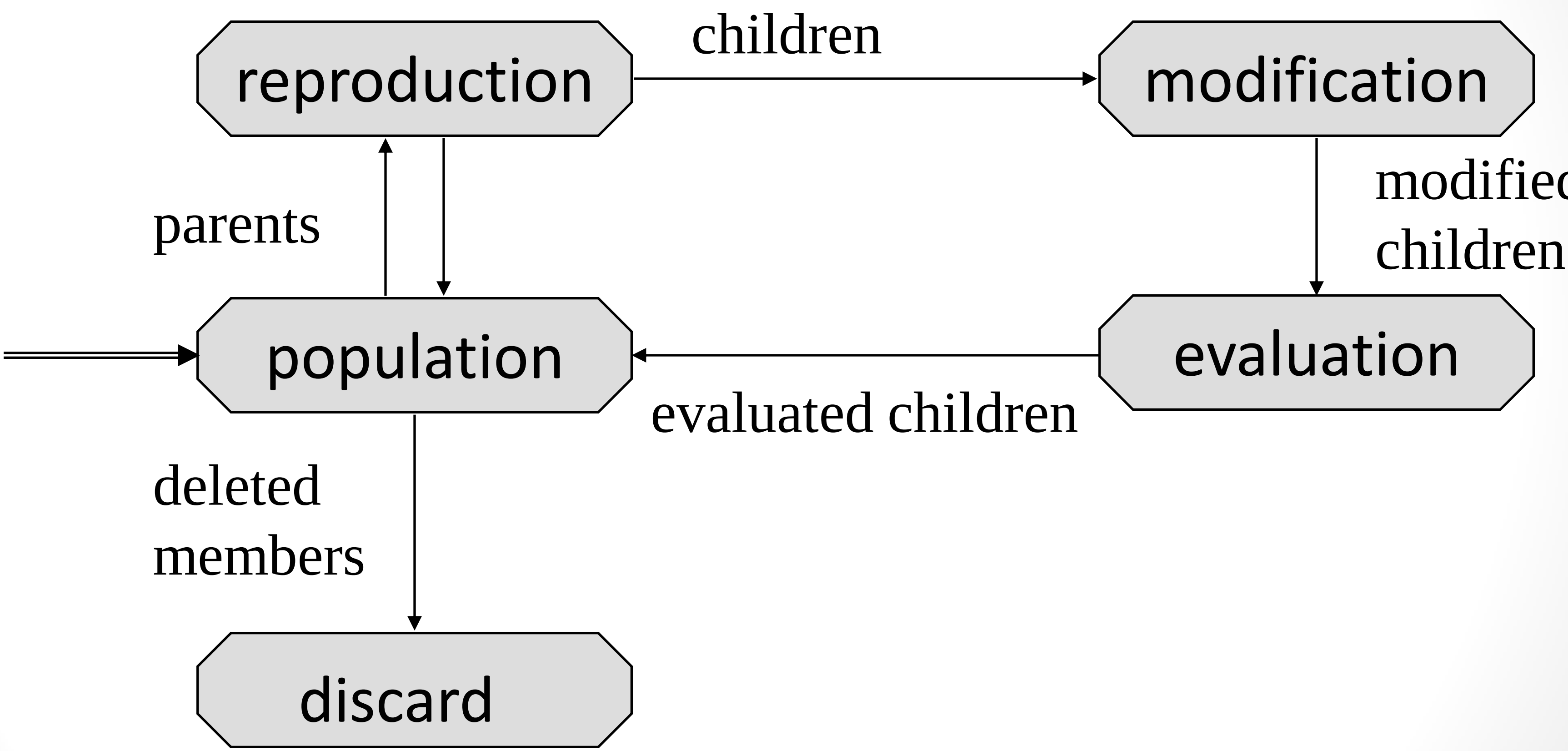
A problem to solve, and ...

- Encoding technique (*gene, chromosome*)
- Initialization procedure *(creation)*
- Evaluation function *(environment)*
- Selection of parents *(reproduction)*
- Genetic operators *(mutation, recombination)*
- Parameter settings *(practice and art)*

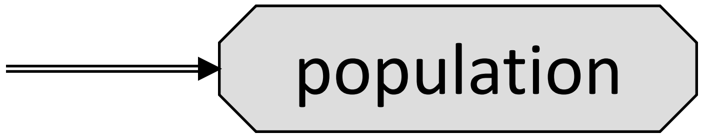
Simple Genetic Algorithm

```
{
  initialize population;
  evaluate population;
  while TerminationCriteriaNotSatisfied
  {
    select parents for reproduction;
    perform recombination and
     mutation;
    evaluate population;
  }
}
```

The GA Cycle of Reproduction



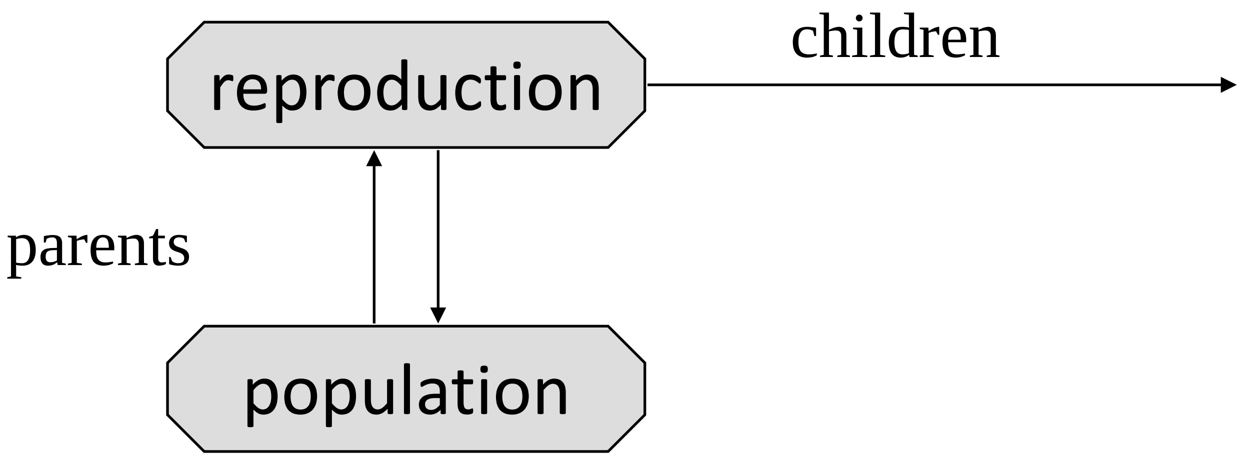
Population



Chromosomes could be:

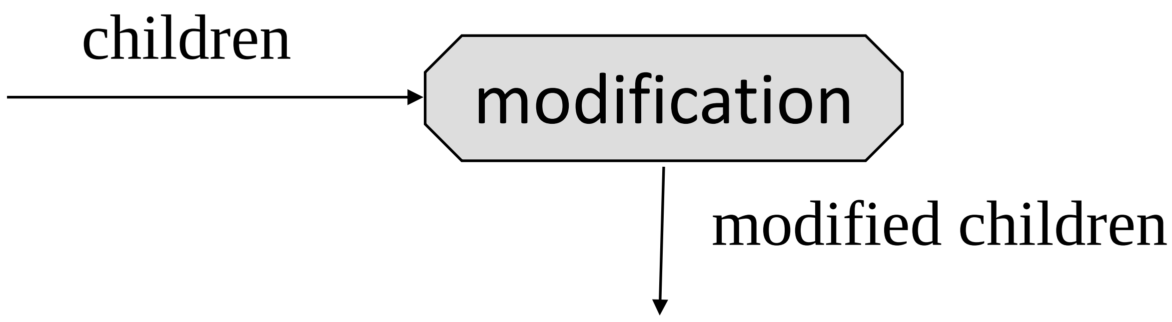
- Bit strings (0101 ... 1100)
- Real numbers (43.2 -33.1 ... 0.0 89.2)
- Permutations of element (E11 E3 E7 ... E1 E15)
- Lists of rules (R1 R2 R3 ... R22 R23)
- Program elements (genetic programming)
- ... any data structure ...

Reproduction



Parents are selected at random with selection chances biased in relation to chromosome evaluations.

Chromosome Modification



- Modifications are stochastically triggered
- Operator types are:
  - Mutation
  - Crossover (recombination)

Mutation: Local Modification

Before:	(1 0 1 1 0 1 1 0)
After:	(0 1 1 0 0 1 1 0)

Before:	(1.38 -69.4 326.44 0.1)
After:	(1.38 -67.5 326.44 0.1)

- Causes movement in the search space (local or global)
- Restores lost information to the population

Crossover: Recombination

*

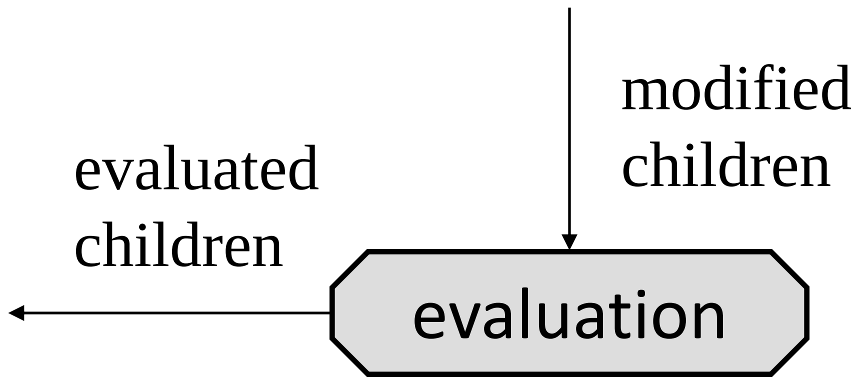
P1 (0 1 1 0 1 0 0 0) → (0 1 0 0 1 0 0 0) C1

P2 (1 1 0 1 1 0 1 0) → (1 1 1 1 1 0 1 0) C2

Crossover is a critical feature of genetic algorithms:

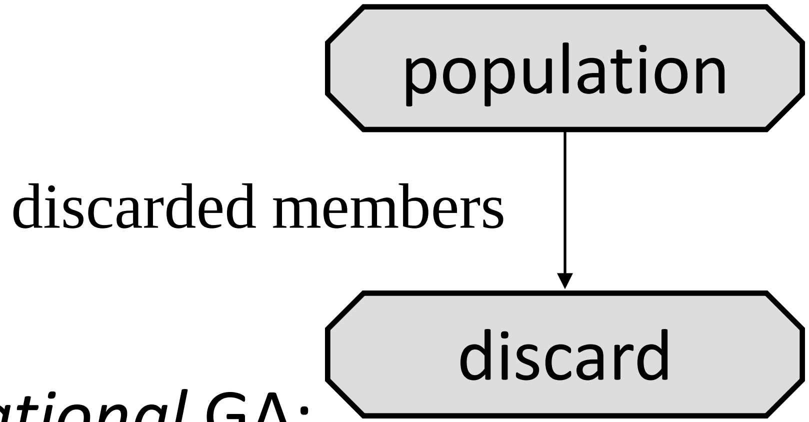
- It greatly accelerates search early in evolution of a population
- It leads to effective combination of schemata (subsolutions on different chromosomes)

Evaluation



- The evaluator decodes a chromosome and assigns it a fitness measure
- The evaluator is the only link between a classical GA and the problem it is solving

Deletion



- *Generational* GA:
  entire populations replaced with each iteration
- *Steady-state* GA:
  a few members replaced each generation

LITERATURE REVIEW

Tsutao Katayama et al., (2004). This paper focused on forming defects (fracture and wrinkle) in the two-stage deep-drawing. In order to solve the problems, it is necessary to improve simultaneously both fracture and wrinkle. For the reason, we had proposed a transfer forming technique, that is a new intermediate process die shape. We investigated the influences of forming defects on the intermediate process die shape, and searched an optimum solution of die shape for improving both of forming defects by using the multi-objective function and sweeping simplex method which is the optimization one.

Sathiya,et al., (2004). Friction welding of austenitic stainless steel and optimization of weld quality. In friction welding, the joints are formed in the solid state by utilizing the heat generated by friction. The objectives of this study are obtaining friction weldment of austenitic stainless steel(AISI 304) and optimizing the friction welding parameters in order to establish the weld quality. Similar austenitic stainless specimens were joined using the laboratory model friction welding machine. The processed joints were tested for their microstructure and strength related aspects. Acoustic emission emanated by the joints during tensile testing was acquired to assess the quality of the joints. Also a method to decide near optimal settings of the process parameters using Genetic Algorithm is proposed.

METHODOLOGY

- Two dissimilar materials such as AISI 4140 and AISI 304 have been considered and joined using friction welding.

Process Parameters with Their Range

Parameter	Range
Friction force, kN (X_1)	15-30
Forging force, kN (X_2)	40-75
Burn-off, mm (X_3)	4-10

- With these 3 input parameters and 2 levels L_8 orthogonal array is generated as given

L_8 Orthogonal Array

Friction force	Forging force	Burn-off
1	1	1
1	1	2
1	2	1
1	2	2
2	1	1
2	1	2
2	2	1
2	2	2

- After this the experimental values of Plain tensile strength, Notch tensile strength, Impact toughness, Micro hardness are listed.

Experiment results for Plain tensile strength

Friction force(kN)- Forging force(kN)- Burn off(mm)	Plain tensile strength (MPa)			Average Plain tensile strength(MPa)
	Trial 1	Trial 2	Trial 3	
15-40-4	623	631	633	629
15-40-10	599	612	607	606
15-75-4	643	651	644	646
15-75-10	601	608	601	603.33
30-40-4	650	656	647	651
30-40-10	622	632	627	627
30-75-4	644	652	647	647.67
30-75-10	638	644	645	642.33

Cont'd..........,

Objective function of Plain tensile strength:

$$Y_p=645.018+0.1092*X_1+0.2547*X_2-8.363*X_3-0.0022*X_1*X_2+0.2018*X_1*X_3-0.00238*X_2*X_3;$$

Experiment results for Notch tensile strength

Friction force(kN)-Forging force(kN)-Burn off(mm)	Notch tensile strength (MPa)			Average Notch tensile strength(MPa)
	Trial 1	Trial 2	Trial 3	
15-40-4	900	913	907	906.67
15-40-10	790	813	797	800
15-75-4	814	857	832	834.33
15-75-10	816	840	831	829
30-40-4	770	783	778	777
30-40-10	761	775	768	768
30-75-4	725	688	703	705.33
30-75-10	769	783	763	771.67

$$Y_n=1278.25-11.034*X_1-3.21*X_2-47.63*X_3-0.0235*X_1*X_2+0.9407*X_1*X_3+0.4206*X_2*X_3;$$

Experiment results for Impact toughness

Friction force(kN)-Forging force(kN)-Burn off(mm)	Impact toughness (J)			Average Impact toughness(J)
	Trial 1	Trial 2	Trail 3	
15-40-4	41	43	43	42.33
15-40-10	24	27	26	25.67
15-75-4	38	36	37	37
15-75-10	25	21	24	23.33
30-40-4	36	35	36	35.67
30-40-10	12	14	12	12.67
30-75-4	32	28	30	30
30-75-10	13	11	13	12.33

Cont'd..............,

$$Y_i=68.8194-0.3171*X_1-0.273*X_2-2.80*X_3+0.0015*X_1*X_2-0.057*X_1*X_3+0.0198*X_2*X_3;$$

Experiment results for Micro hardness

Friction force (kN) **Forging force (kN)** **Burn off (mm)**	**Micro hardness (HV) at weld center**			**Average micro hardness(HV)**
	Trial 1	Trial 2	Trial 3	
15-40-4	357	360	348	355
15-40-10	325	320	331	325.33
15-75-4	358	355	362	358.33
15-75-10	316	310	321	315.67
30-40-4	405	410	397	404
30-40-10	371	375	367	371
30-75-4	412	415	399	408.67
30-75-10	370	377	365	370.67

Y_m=328.270+2.697*X_1+0.057*X_2-3.67*X_3+0.01015*X_1*X_2+0.0074*X_1*X_3-0.042*X_2*X_3;

- Combined objective function written in Matlab for genetic algorithm is

Y=Y_p+Y_n+Y_i+Y_m;

RESULTS AND DISCUSSIONS

Process parameters	Experiment values	Program values	% variation
Plain tensile strength, MPa	629	633.70	0.74
Notch tensile strength, MPA	906	902.81	0.35
Impact toughness, J	42.33	42.51	0.42
Micro hardness, HV	355	356.03	0.29

- The theoretical values of plain tensile strength, notch tensile strength, impact toughness, micro hardness which come after the run of genetic algorithm are nearly closed to corresponding experimental results.

- In this work, all objective functions are combined into one single objective without giving any weighted values between them.

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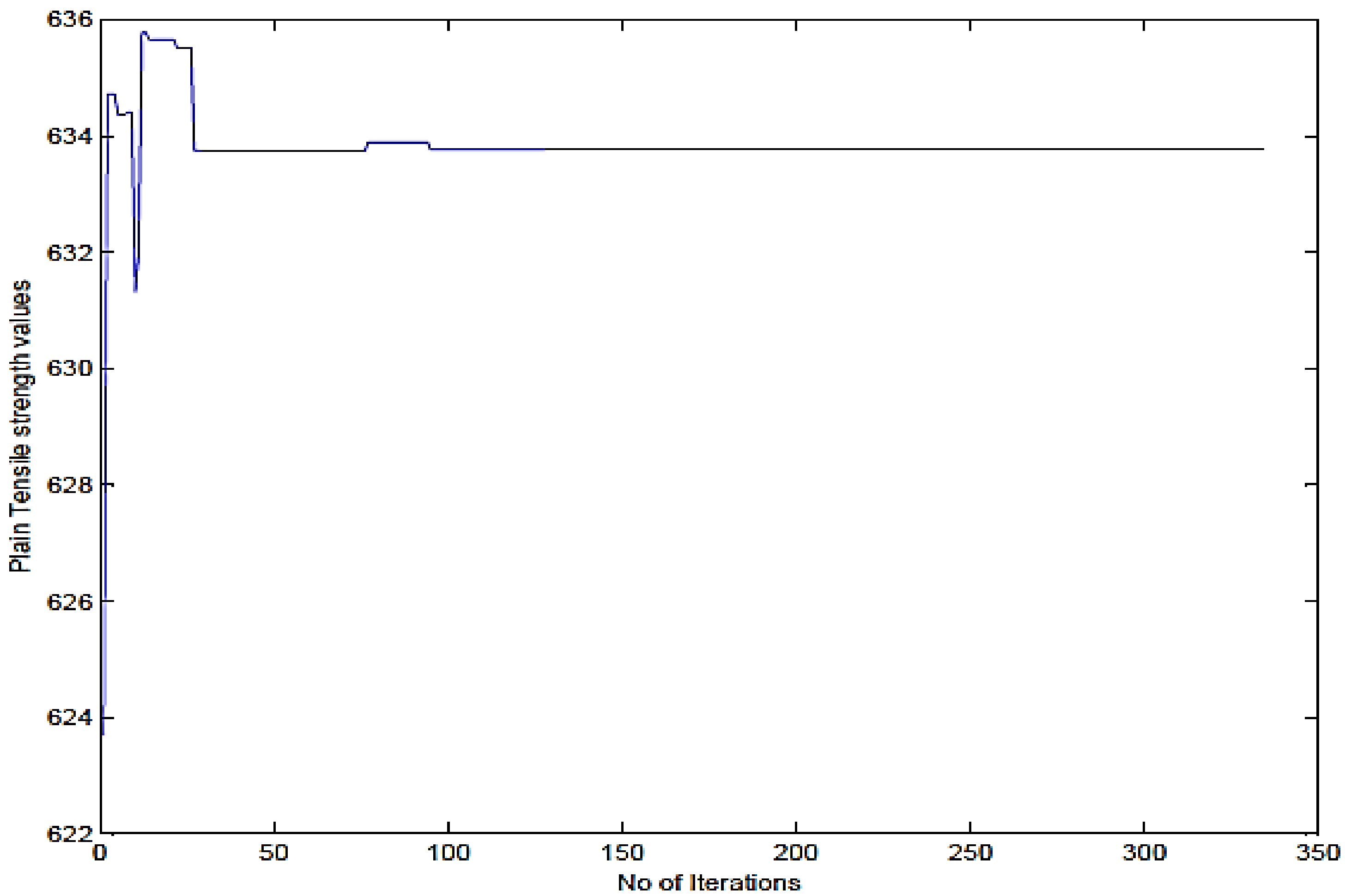

Plain tensile strength vs no of iterations.

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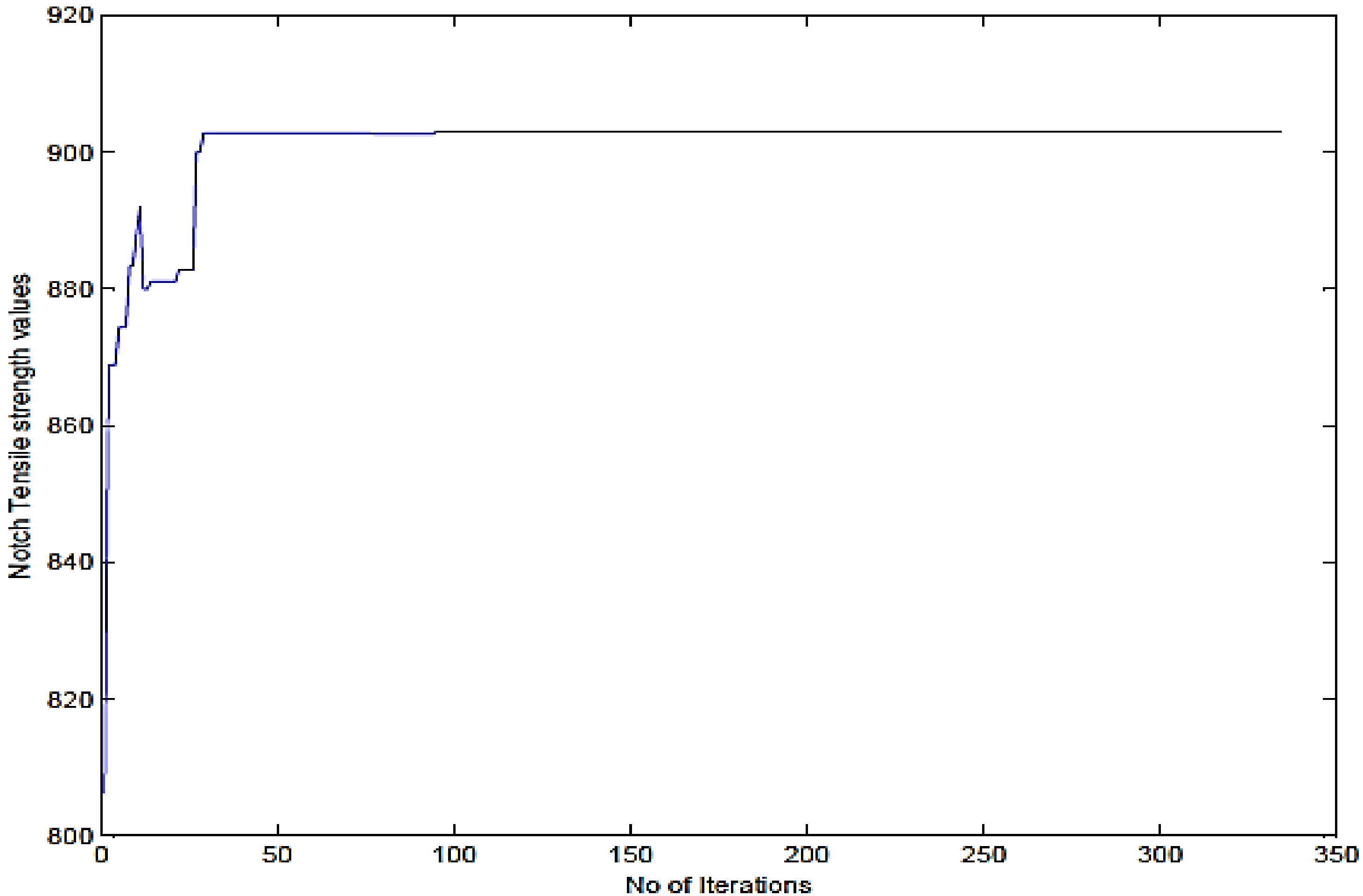

Notch tensile strength vs no of iterations

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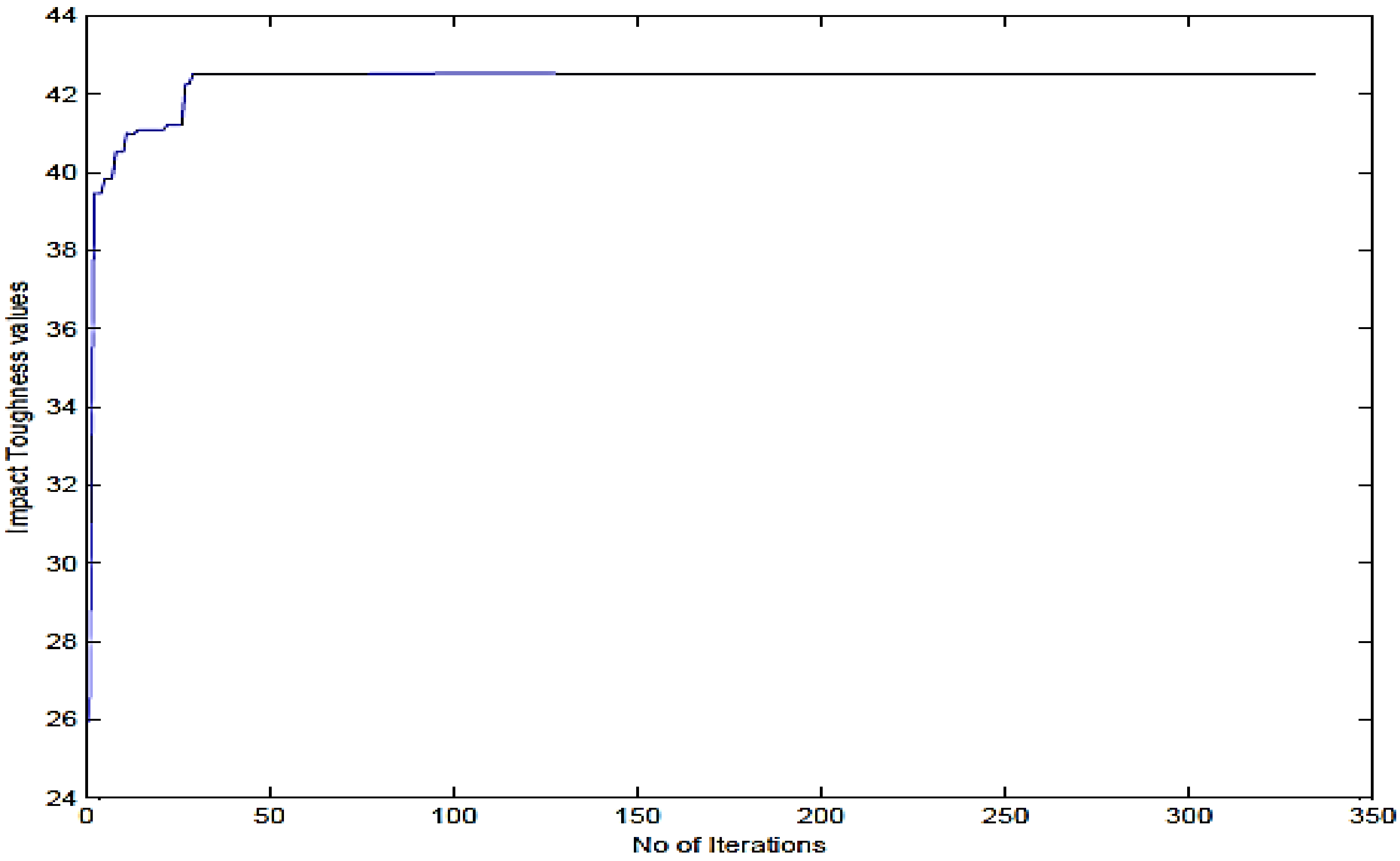

Impact toughness vs no of iterations

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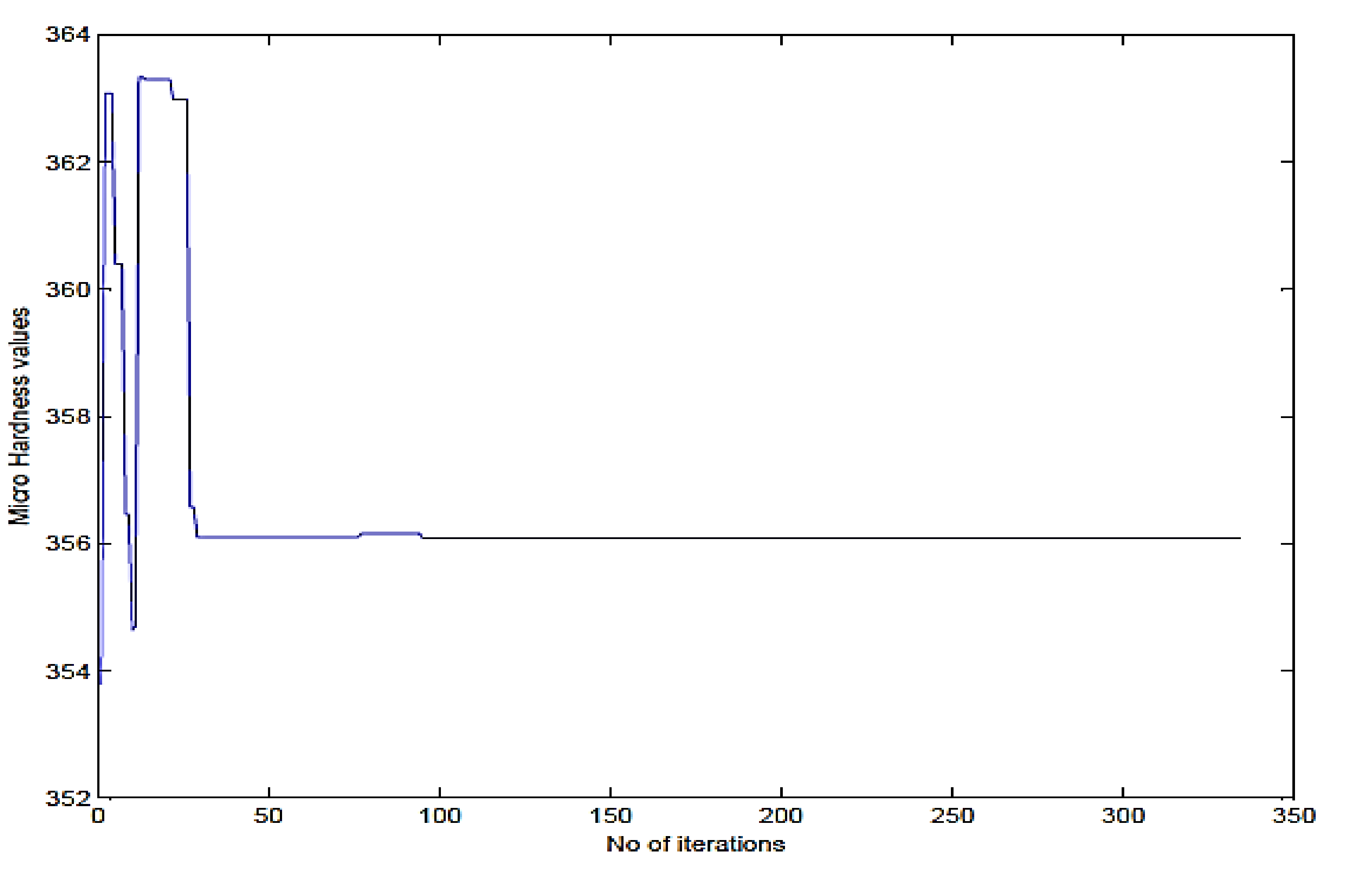

Micro hardness vs No of iterations

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CONCLUSIONS

- The GA is employed in the present work to optimize the process parameters such as friction force, forging force and burn-off with the objective of maximizing the plain tensile strength, notch tensile strength, impact toughness and micro hardness.
- It is observed that the optimum values obtained using GA are very close to the experimental values. Hence the GA program developed in this work can be used to optimize the parameters accurately.

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THANK YOU