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A Brief Review on Optimization of Injection Molded Parts by Using CAE and Artificial Intelligence: ANN PSO Approach

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Abstract: The quality and cost of a product are essential parameters which attract the clients. It is difficult to achieve the desired quality at the cheap production cost. Hence it is necessary to use qualitative methods in production processes and reduce frivolous costs at the same time. Injection molding process parameters directly influence the quality and cost of a product. Thus it is important to optimize these parameters. However it is very arduous and complex task. If Artificial Neural Network (ANN) and Particle Swarm Optimization (PSO) are combined with advanced Computer Aided Engineering (CAE) softwares, which forms an Artificial Intelligence (AI) platform that can be proved as an effective solution for optimization of injection molding process parameters. This paper provides a brief review of such work that can bring a revolution in production processes in future. The finite element method helps in deep investigation of filling and packing conditions on a reduced set of process parameters. The ANN provides feasible results for the input whereas the PSO finds the optimal solution amongst these results obtained. Thus the integration of all these methods can be useful for enhancing precision, increased automation and optimized operating parameters. The combination of these methods helps in reduction in time required for planning, optimization of operating parameters, reduction in volumetric shrinkage and prediction of mechanical properties accurately. Thus the review confirms the efficiency of integration between CAE and AI methodologies to identify optimal parameters for the injection molding process.
***Keywords:** Artificial Neural Network, Particle Swarm Optimization, Injection molding, Finite Element Method*

I. INTRODUCTION

Injection molding is a manufacturing process for producing parts by injecting material into a mold. Injection molding is the very rapidly used process for producing plastic products. It's parameters are plays very important role as they directly influence the quality and cost of the products. However, the optimization of these parameters is very arduous and complex task. When injection temperature increases, melt viscosity decreases, due to which cavity pressure and shear stress also reduces. Also, if injection temperature is high, cooling time get increased due to which productivity decreases. From this, It is clear that an optimization algorithm must be used for optimization of this conflicting process parameters to obtain optimum parameters and produce a high quality part at minimum cost[1].So it is very important to optimize these injection molding parameters and it can't be done with traditional tedious methods. Therefore, to reduce computational cost, labour and time many researchers are taking help of integration between CAE software's and Artificial intelligence. Hot Runner Injection Molding is shown in Fig. 1.

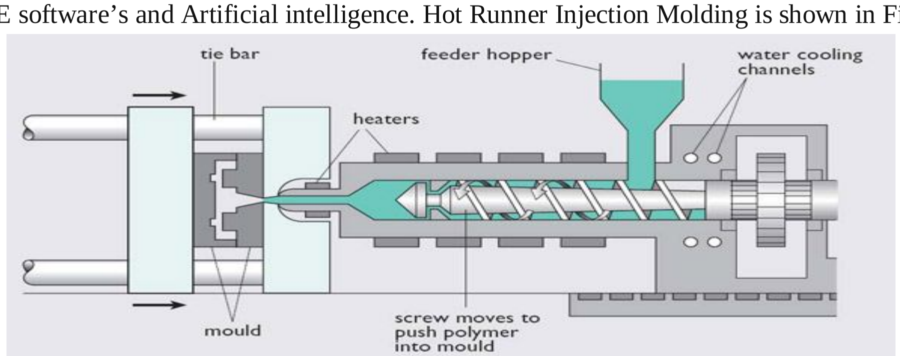

Fig. 1: Hot runner Injection Molding

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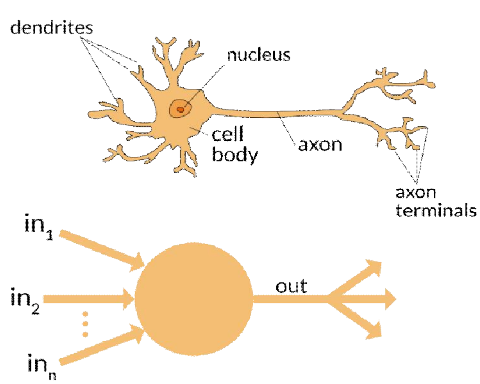
A. Aims and Objectives

This paper provides a brief review of such work that can bring a revolution in production processes in future. Also this paper provides very beneficial ideas for further projects and researches of such type in future.

B. Description Of Current Used Software's

1) *Artificial Neural Network (ANN).*ANN is powerful method for prediction of nonlinearities. These mathematical models have individual processing units called neurons that simulate neurons such as in human nervous systems as shown in Fig.2. Each neuron sums weights to the inputs and then performs a linear or nonlinear function to the result sum values and provides the outputs. The processing units are arranged in layers as shown in Fig.3. And they are combined with each other through excessive connectivity. Back propagation network (BPN) is one of the most popularly used ANN.[2]
2) *Neural networks resemble the human brain in the following two ways* -
a) A neural network acquires knowledge through learning.
b) A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

Artificial neural networks can be viewed as weighted directed graphs in which artificial neurons are nodes and directed edges with weights are connections between neuron outputs and neuron inputs. The Artificial Neural Network receives input from the externally such as from CAE software's in the form of pattern and image in vector form. Each input is multiplied by its corresponding weight. Weights are the information used by the neural network to solve a problem. Weight represents the strength of the interconnection between neurons. The weighted inputs are all summed up inside artificial neuron. Bias has the weight and input values '1'. The sum can be any numerical value in the range from 0 to infinity. In order to limit the response to arrive at desired value, the threshold value is set up. For this, the sum is passed through activation function. The activation function is set of the transfer function used to get desired output. There are linear as well as the non-linear activation function. Such commonly used activation function are— tan hyperbolic sigmoidal functions(nonlinear) and binary, sigmoidal



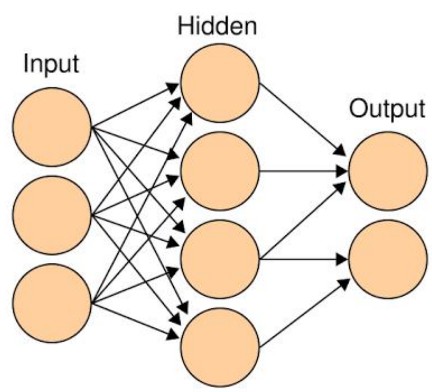


Fig.2: Comparison between Human Nervous   Fig. 3: Artificial Neural Network System and ANN processing unit

3) *Back propagation network.*BPN have hierarchical feeding forward network architecture. In it's classical structure, the output of each neuron in each layer is sent directly to each neuron in the above layer.BPN is trained by repeatedly processing a sequence of input and output pattern sets to the network. The network slowly learns the input and output relationship by modifying the weights to reduce the error between the actual outputs and predicted outputs of the training setback propagation is a method used in artificial neural networks to calculate the error contributed by each neuron after a set of data is processed. This is used by an ANN optimization algorithm to adjust the weight of each neuron, completing the learning process for that case.[4]
4) *Particle Swarm Optimization.* Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Russell C. Eberhart and Dr. James Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. It is inspired from the for aging behavior of birds or fish schooling. In PSO, the individuals called as particles, are collected into a swarm and fly through the problem space by following the optima particles. Each particle has a memory by which they remember the best position of the search space they has ever visited. If particular particle remembers the best position it has visited it is referred to as pbest. There are two method for remembering the neighbors best position, lbest and gbest. The lbest is related to the best position of the particle in the neighbors of the particle itself and gbestis the best position

recorded by the entire swarm. Each particle has an adaptable velocity, respective to which it moves in the search space. Thus, its movement is an resultant acceleration to ward sits best and towards the lets or best[5].

5) *Bee Colony Algorithm.* Artificial bee colony algorithm is an optimization technique that is inspired from the foraging behavior of honey bees, and has been successfully applied to various practical problems. Artificial bee colony algorithm belongs to the group of swarm intelligence algorithms and was proposed by Parabola in 2005.A colony of honey bees can extend itself over long distances (more than 10 km) and in multiple directions simultaneously to exploit a large number of food sources. The foraging colony sends scout bees to these flower patches. Scout bees move randomly from one patch to another. After returning to the hive the scout bees who found a promising patch go to the dance floor. On the dance floor scout bees perform a dance called waggle dance which gives information about the flower patch they found. The dance gives information about the quality rating, direction and distance of the flower patch. With this information, the colony sends the bees to the flower patches. The more the rating of the flower patch is, the more the follower bees are sent there. While harvesting from a patch, the bees monitor its food level. If the patch is still good enough as a food source then it will be advertised in the next waggle dance and more bees will be recruited to that source.[6-7]And as such the Bee Colony Algorithm works.
6) *Genetic Algorithm (GA).* A genetic algorithm is a met heuristic inspired by the process of natural selection in nature that belongs to the larger class of evolutionary algorithms. Genetic algorithms are commonly used to generate high-quality solutions for optimization and search problems by using methods of bio-inspired operators such as mutation, crossover and selection.[8]
The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:
   a) Heredity rules combine two parents to form children for the next generation.
   b) Selection rules select the individuals, called parents, that contribute to the population at the next generation.
   c) Mutation rules apply random changes to individual parents to form children.

Ina genetic algorithm, evolution takes place of the population of candidate solutions for optimization problems toward better solutions. Each candidate solution has a set of properties which can be mutated. Solutions are represented in binary as strings of 0s and 1s, however other encodings are also possible.

The evolution starts from a population of randomly generated solutions, and is an repetitive process, with the population in each repetition called a generation. And each generation, the fitness of every individual in the population is evaluated. The more fit individuals are randomly selected from the current population, and each individual's genome is modified to form a new generation. The new generation of candidate solutions is then used in the next repetition of the algorithm. The algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

It has many applications such as in Gene expression profiling analysis, Feynman-Kac models, Financial mathematics, File allocation for a distributed system, Filtering and signal processing, Finding hardware bugs, Game theory equilibrium resolution, Genetic Algorithm for Rule Set Production, etc.[9]

C. *Finite Element Method*

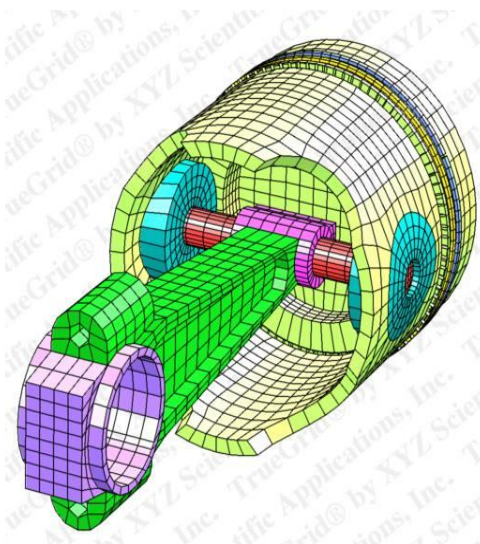


Fig. 4: Finite Element Mesh for a Rod & Piston

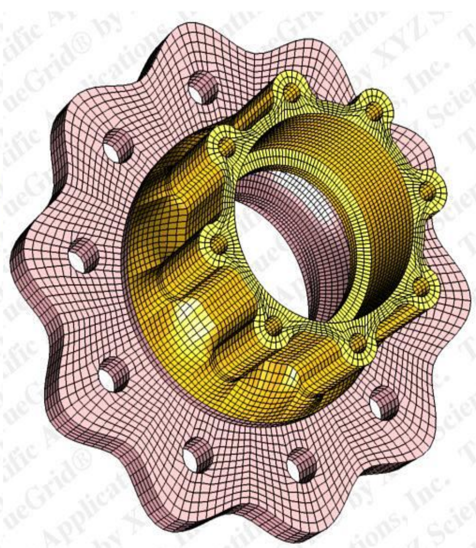


Fig. 5: Finite Element Mesh of a Wheel Hub

The finite element method formulation of the problem results in a system of algebraic equations. To solve the problem, it subdivides a large problem into smaller, simpler parts as shown in Fig.3 and Fig. 4 that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variation methods from the calculus of variations to approximate a solution by minimizing an associated error function.
Advantages of dividing the whole domain into simpler parts are

1) We can accurately represent a complex geometry
2) dissimilar material properties can also be included
3) Easy representation of the total solution
4) local effects can easily be captured[10].

D. Functioning Of Integration Of ANN and PSO With CAE Software

For understanding the working of such integration between CAE software and Artificial Intelligence, the functioning of integration of ANN and PSO with CAE software is given as an example.
The proposed approach of this is to develop an integrated environment for the optimization of Warpage of the products by integration of Finite Element and Artificial Intelligent approaches. Finite Element (FE) Method allowes the deep investigation of filling and packing conditions with reduced set of process parameters and Artificial Neural Network enlarges the search space by predicting results on points different from those of numerical simulations and PSO was also involved in the optimization stage.
Firstly, the CAD model of the product was imported and then it is converted into a Finite Element mesh. After creating the FE mesh, the solution space is defined. For the defining the solution space two approaches are used. First, a regular solution space equal to that obtained with a 2nFull Factorial technique is defined. In second approach, initial solution set in which process parameters were randomly distributed is considered.
After that defining the solution spaces numerical simulations are performed on them and main response variables are evaluated. Then experimental tests get carried out to justify the FE model. The input-output pattern are then extracted and sent to ANN. A feed-forward neural network is then used to predict these patterns. For training the ANN, training data is used and the learning process is completed when Mean-Square Errors between existing data and predicted data on training are less than a fixed value. The PSO is directly used for performing computations on data provided by ANN for identifying optimal solutions[5].
This integrated environment was developed by R. Spina(Department of Mechanical and Management Engineering, Polytechnic di Bari, Vaile Japigia 182, 70126, Bari, Italy).

II. RESULTS

When R. Spine applied the method to a real component which is a cover of an electric assembly and is characterized by box shape with internal ribs and made of Ultramar B3S (un-reinforced PA6 material) of BASF Company. They found that the volumetric shrinkage of entire part was more uniform and the volumetric shrinkage has reduced. Also the surface finish was very good[5].
Also, many of such integration of CAE and AI methods have provided very good results such as
Femi Yin, Hoagie Ma and Lin Huda develop an integration between Back propagation network (BPN) and Genetic Algorithm (GA)with CAE software Mold flow for optimization of injection molding process parameters.
When they applied this integration to real component which has width of 200mm, length of 200mm and maximum part thickness of 2mm.The material of the part is PP. And the material mode of PP with the trade name of BP
Amoco 1046 and manufactured by BP Chemicals.
They found that the optimized war page value which was before 3.307 mm, has reduced by 66.9% to 1.092 mm, obtained by using Mold flow recommended process parameters[11].
T.S. Kaki, T. Suzuki, W.B. Bee, Y. Lehar and H. Homer developed integration between neural network and computer simulation using 3D Timor v.6.11 CAE software, to improve surface profile of injection molding optic lens.
They applied this integration on an a spherical optic lens with an effective diameter of 12.48mm used in
8mm camcorders. Polymethylmethachrilate (PMMA), polymer with superior transparency compared to other materials was used as the material in optic lens molding.
They found that ANN and CAE analysis agreed well with the experimental results. And the optimization method is feasible in predicting the tendency of target values, such as quality of molded parts[12].
Sheen Change, Wang Lidia , Li Qi an developed an integration between Artificial Neural network (ANN) And Genetic Algorithm (GA) with CAE software's for Optimization of injection molding.

They applied this integration on a plastic part which is the top cover of an industrial refrigerator. The main plane of the part has a thickness of 2–3.5 mm, and the ribs have the thickness of 1–1.5 mm. The polymer material used for molding the cover is ABS.
They found that the combination of ANN and GA with CAE gives satisfactory results for the optimization of injection molding .
They also found that this optimization method has great potential in complicated industrial applications[13].
Femi Yin, Hoagie Mao, Lin Huda, Wei Goo, Mao sheng Shoo developed an integration between back Propagation Neural Network with CAE software Mold flow for war page prediction and optimization of plastic products during injection molding.
They applied this integration to the automobile glove compartment cap. Its width is 230mm , length is 350mm and thickness is 2.5mm. The material of the glove compartment cap is polypropylene (PP). And the material mode of PP with the trade name of BP Amoco 1046 and manufactured by BP Chemicals.
They found that the neural network method can predict the war page of the plastic component within 0.001s and with the prediction error less than 2%. Also the optimized war page value which was 2.358 mm initially got reduced by 32.99% to 1.580 mm.
And the cooling time has also got decreased by 50% comparing to that of the recommended process parameters. And the final product can satisfy with the matching requirements and fit the automobile glove compartment well[14].

III. CONCLUSION

Thus the integration of all these methods can be useful for enhancing precision, increased automation and optimized operating parameters. The combination of these methods helps in reduction in time required for planning, optimization of operating parameters, reduction in volumetric shrinkage and prediction of mechanical properties accurately. Thus the review confirms the efficiency of integration between CAE and AI methodologies to identify optimal parameters for the injection molding process.

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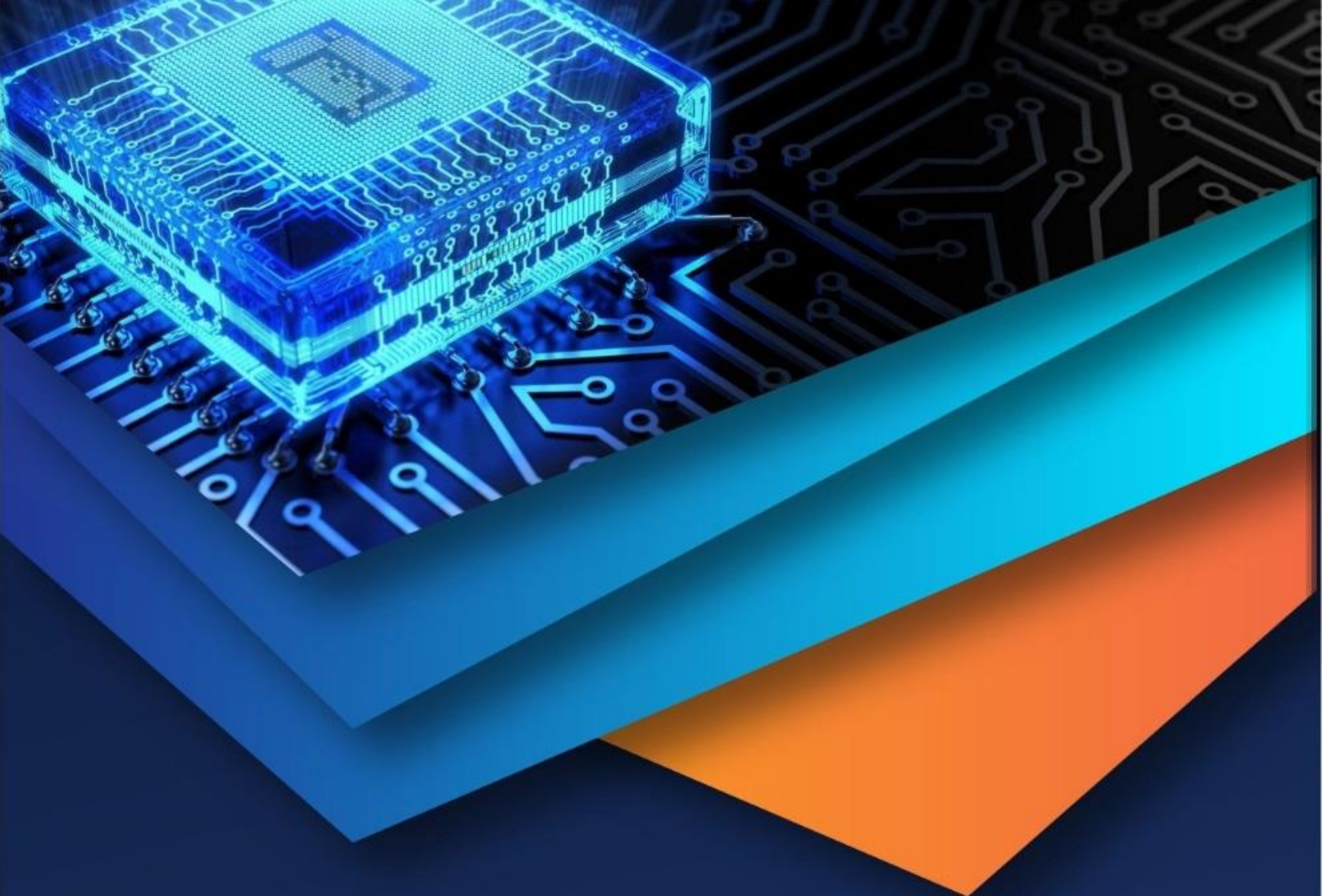

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