A Performance Prediction of Worm-Worm Wheel and its Multi Objective Design Parameter Optimization Based on Genetic Algorithm

Mokara Bharati*, V. DeepikaPoornima*, S.Jyothrimai*

*Department of Mechanical Engineering, MVGR College of Engineering,

Abstract **-**The optimization of gear design is a challenging problem as the design variables are interrelated to each other. Various methods have been proposed for solving such problems. This paper aims in developing a methodology for acquiring the desired worm gear design configuration by altering the optimum set of worm gear design parameters which are suitable for the required performance by associating it with SVM (Support Vector Machine). An evolutionary technique like Genetic algorithm (GA) is also used along with it for optimizing the worm and worm wheel with multi objectives, the main object is to attain high wear capacity by considering module, power, velocity ratio, and speed as design parameters. Center distance and strength of worm gear are the constraints taken into consideration.

Index terms **-** Genetic Algorithm, Multi objective optimization, Worm and Worm Wheel database, Support Vector Machine

I. INTRODUCTION

Worm gears are used for transmitting power between two non-parallel, non-intersecting shafts and in applications where the speed reduction ratio is between 3:1 and 100:1 and in situations where accurate rotary indexing is required. High gear ratios of 200:1 can also be obtained. In the evaluation of worm and worm gear designs, certain basic gear design performance metrics such as tooth bending stress, contact stress, surface fatigue strength, allowable surface fatigue stress, tooth surface strength of gear and pinion etc. are to be carefully considered. The effectiveness of the gear design can be improved only when all these metrics are controlled properly. Despite attempts by several gear designers to improve the efficiency of the gears, the control of all these metrics and achieving a desired performance is a very complicated task. In this paper, an attempt is made to develop a prediction model based on SVM that maps the gear design parameters such as module, velocity ratio, power, speed, etc. with gear design performance metrics. The benefit of such prediction model is a significant reduction in processing time as well as enhanced flexibility in the development of worm gear designs. Yet another problem is however faced by the designer in terms of arriving at the right combination of design parameters in order to achieve a required performance metrics. Currently, this task is highly dependent upon designer expertise. In this work, GA has been combined with SVM in order to develop a fast and accurate search and optimization model.

II. LITERATURE SURVEY

Extensive research has been made for predicting the gear design performance metrics to reduce lead time of a product. In conventional method, distributed support vector machines (SVM) algorithms are trained over pre-configured intranet/internet environments to find out an optimal classifier. These methods are very complicated and costly for large data sets. Hence, I.W. Tsang, et.al, [1] proposed a method that is referred as the Cloud SVM training mechanism (Cloud SVM) in a cloud computing environment with Map Reduce technique for distributed machine learning applications. P.H. Chen et.al, [2] studied sequential minimal optimization type decomposition methods under a general and flexible way of choosing the two-element working set. F. Chang et.al, [3] shows that decision tree can be used to accelerate the training and testing of support vector machines (SVMs). M. Yaman et.al, [4] In this papers discussed about a non-conventional algorithm namely genetic algorithm is presented for minimization of power-loss of worm gear mechanism with respect to specified set of constraints.. V. Savsani et.al, [5] presents two advanced optimization algorithms known as particle swarm optimization (PSO) and simulated annealing (SA) to find the optimal combination of design parameters for minimum weight of a spur gear train. C. Gologlu et.al, [6] He is discussed about automated preliminary design of gear drives by minimizing volume of gear trains a stochastic approach Genetic Algorithm (GA) was applied to a parallel axis two stage helical gear trains problem. S. Caballero et.al, [7] in his paper presented a genetic algorithm (GA)-based optimization procedure for the design of gear transmissions and discussed about the importance of Evolutionary Techniques like Genetic Algorithm (GA) . Y. K Mogal et.al, [8] in his paper made an attempt to optimize worm and worm wheel with multiple objectives, The main objective function is to minimize volume of worm and worm wheel and remaining objectives are taken as constraints such as centre distance, deflection of worm and beam strength of worm gear.

III. WORM-WORM GEAR DESIGN

The problem statement of the current work is, to carry out optimization of worm and worm wheel considering maximization of Wear capacity of worm and worm wheel as an objective. A worm and worm wheel design performance prediction model was first developed using SVM. In order to develop a SVM based prediction model, a variety of gear design models has been developed through analytical approach. The various design parameters affects the analytical analysis of the worm and worm gear, which are taken as velocity ratio, power, speed, module. Several gear design models in the range of module 4mm-16mm, velocity ratio 18-31, teeth on worm 1-5, power 0.1-300KW, speed of the pinion shaft 40-3000 rpm are taken for analytical analysis to evaluate the gear design performance metrics such as bending fatigue stress, wear capacity, heat dissipation, heat generation, for each of these designs it is executed separately in MATLAB. Several design models has been performed and a huge data base has been obtained to run SVM prediction model using the analytical analysis based program. This algorithm has been developed in such a way that the required input design parameters and the required output performance metrics are evaluated using the procedure for gear design according to American Gear Manufacturing Association (AGMA) standard.

A. Performance Analysis Using Data Base

In order to evaluate performance of worm gear design analytical analysis data base, bending fatigue, wear capacity, heat generation, and heat dissipation. The analytical analysis of worm and worm wheel was done by varying velocity ratio, module, power, and speed. The data related to performance, was simultaneously recorded and the results obtained from theoretical analysis were plotted. Output parameters were executed in MATLAB. The results are compared with AGMA standards using standard gear relations. [9-11]

B. SVM(Support Vector Machine) Prediction Model

In this paper, an attempt is made to develop a forward mapping model using SVM to predict the worm and worm gear performance under varying design conditions. The SVM model can easily be developed by assigning a few parameters namely the kernel function, the cost function etc. Unlike with ANN (Artificial Neural Network) where the architecture has to be developed in advance, the SVM model is easy to build and at the same time it generates a unique solution after training. The goal of SVM is to find out a function that gives a deviation of error from the actual given output and at the same time is as flat as possible. This is achieved by mapping the training patterns from the input space to a high dimensional feature space in such a way that the data which could not be separated by a linear function in the input space can be separated in the feature space. Thus, in arriving at a suitable SVM Model for the given sparse data, the only parameters that the user deals with and has to specify are the kernel function, type of loss function, the error goal, the constant and the width of the radial basis function. This makes it convenient to use SVM in the prediction of the output variable for a given combination of input variables especially in a situation where collection of data for training the model is difficult. Analytical analysis was conducted and the data generated for various design conditions. In order to develop a prediction model a program has been developed and executed in MATLAB. Input parameters for the SVM model were taken as velocity ratio (18-31), module (4-16mm), power (0.1-300KW) and speed (40-3000rpm). The output parameters were taken as bending fatigue, wear capacity, heat generation. A total of 200 data points were obtained from analytical analysis of which 190 were used to develop the model.

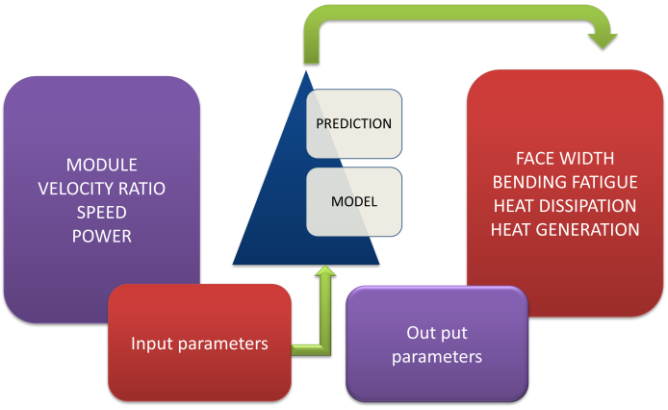

Fig 1- SVM forward mapping prediction model

C. Gear Design Optimisation With Genetic Algorithm (GA)

Genetic algorithm is based on evolutionary processes and Darwin's concept of natural selection. It works on the principle that, only the fittest populations will survive while the bad populations are weeded out. The same concept is extended to the mathematical optimization problems where only good design points are selected while the bad design points are neglected. Figure 2 shows that an initial population is chosen randomly at the beginning and fitness of initial population individuals is evaluated. Then an iterative

process starts until the termination criteria have been run across. After the evaluation of individual fitness in the population, the genetic operators, selection, crossover and mutation are applied to breed a new generation. The newly created individuals replace the existing generation and re-evaluation is started for fitness of new individuals. The loop is repeated until acceptable solution is found. In this paper Multi-objective optimization of worm and worm wheel is carried out. The main issue in design of worm and worm wheel is, it should be compact i.e. its wear capacity high, centre distance should be less, there should be no deflection of worm and also it should have high strength. All these objectives are considered here to get the best performance of worm and worm wheel.

D. Reverse Mapping Methodology

The estimation of gear design performance metrics for a worm gear pair requires representation of the influence of design parameters on gear design performance metrics and estimation of the optimum design parameters that would yield a required performance. This involves a combination of regression mapping and optimization. SVM and Genetic Algorithms (GA) are used in this concept to build a forward-reverse mapping model for optimization of gear design performance. As shown in Figure 2, the gear design parameters are sent to the software-based forward mapping model that has been built to map the relationship between the design parameters and performance metrics. For the given operating conditions, the forward mapping model predicts the performance. The desired optimum performance is defined so that the designer always operates under these conditions. This is achieved by linking the artificial intelligence based reverse mapping model with the forward mapping model. The reverse mapping model estimates the optimum performance metrics from a range of design parameter solutions that satisfy the require model.

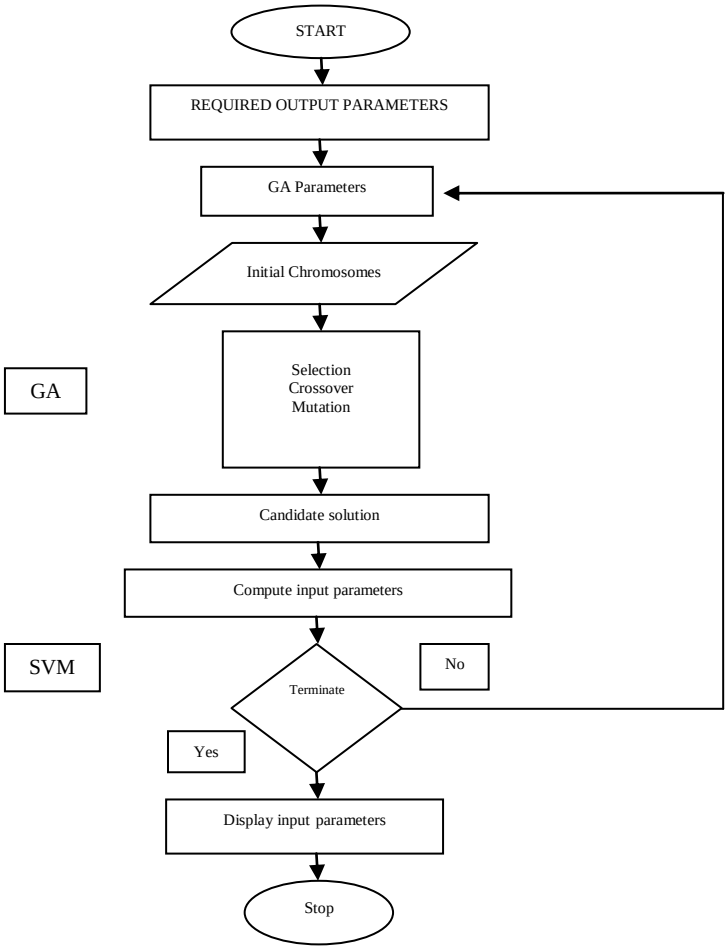

Fig 2: Flow chart of the Support vector machine and Genetic algorithm reverse mapping methodology

IV. RESULT AND ANALYSIS

Support vector machine (SVM) Results Analysis - The predicted values from the SVM model were found to be very close to the actual values obtained through analytical analysis. In the case of bending fatigue, it can be observed from Figure 3 and table 1 that the SVM predicted values and the values obtained from experimentation are fairly close. As comparison between theoretical and SVM approach the correction values are dominant while error values are less in number. The output parameters are bending fatigue, wear capacity, heat generation, and heat dissipation ha 70%, 69%, 90%, 80%. Similar values lies in between 20% to 40% from result. It is observed that the SVM model developed is able to map the relationship between design parameters and performance attributes very accurately.

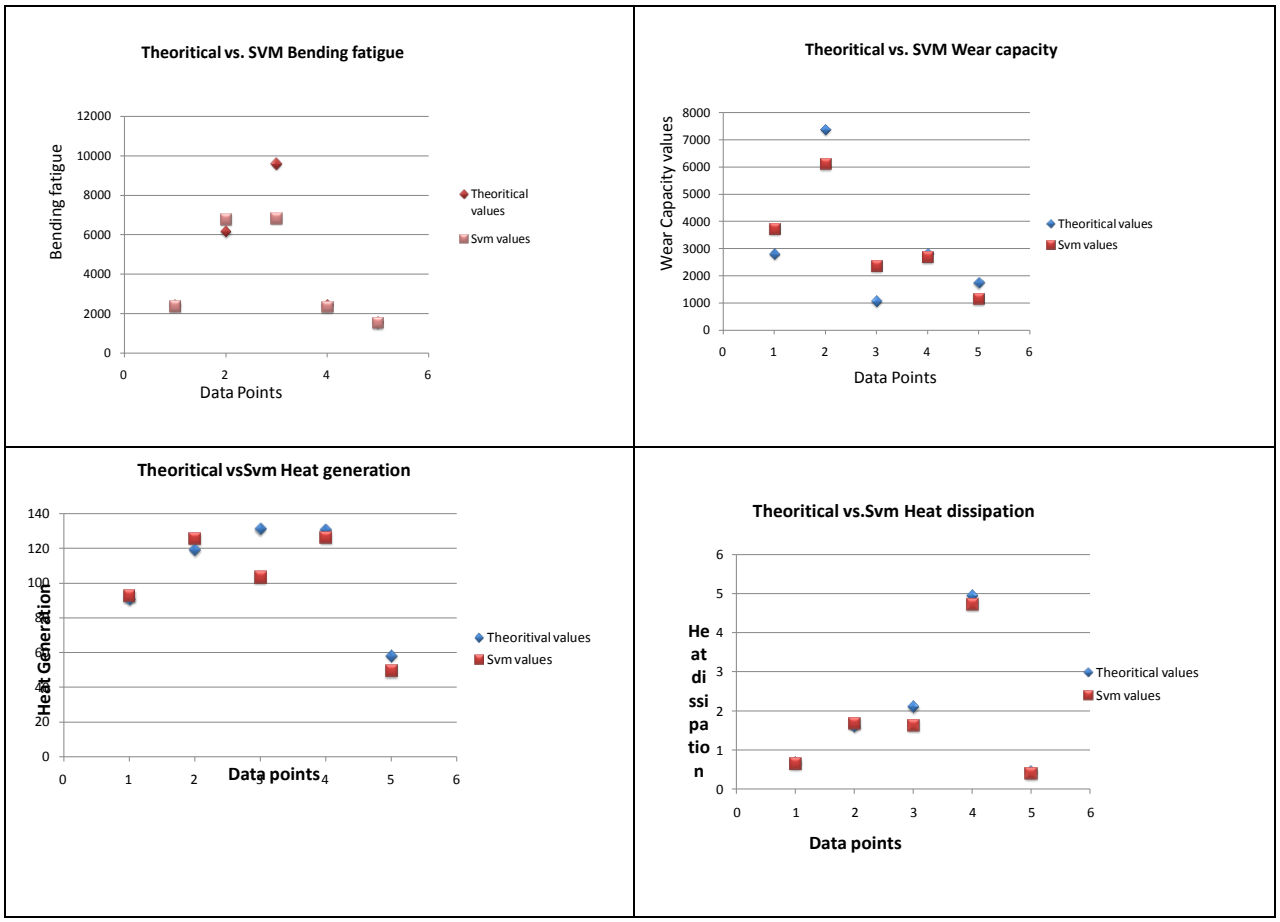

Fig 3: Shows the theoretical and support vector machine prediction model results for bending fatigue, wear capacity, heat generation, Heat dissipation

Table1 - Theoretical and SVM values of all the performance metrics

OUT PUT PARAMETERS											
Input Parameters				Wear Capacity		Bending Fatigue		Heat generation		Heat dissipation	
Power W	Speed N	V.R	m	Theoretical	SVM	Theoretical	SVM	Theoretical	SVM	Theoretical	SVM
900	1500	28	5	2435	2388.4	2812	3732.4	90.5500	92.4998	0.6864	0.6520
900	1500	29	8	6168	6806.3	7377	6123.9	119.2000	125.7791	1.6050	1.6842
900	1500	27	10	9603	6895.3	1069	2374.7	131.0000	103.2990	2.1060	1.6335
900	1500	28	16	2445	2356.8	2823	2686.1	130.5000	126.2198	4.9390	4.7269
700	1200	27	4	1569	1543.3	1747	1157.9	58.2000	49.5800	0.4456	0.4061
700	1200	30	5	2435	2367.6	3013	3899.3	62.9000	64.2460	0.7613	0.7435
700	1200	29	8	6168	6658.1	7377	6124.5	81.7000	85.5800	1.6050	1.6376
800	1800	29	10	9603	9525.9	1148	2406.7	116.5000	118.7446	2.3440	2.3114
1000	1800	28	4	1569	1708.6	1812	1243.5	101.2000	100.0829	0.4704	0.4713
200	600	20	16	2445	2483.2	2016	1968.5	23.1000	23.7333	3.0180	3.0455

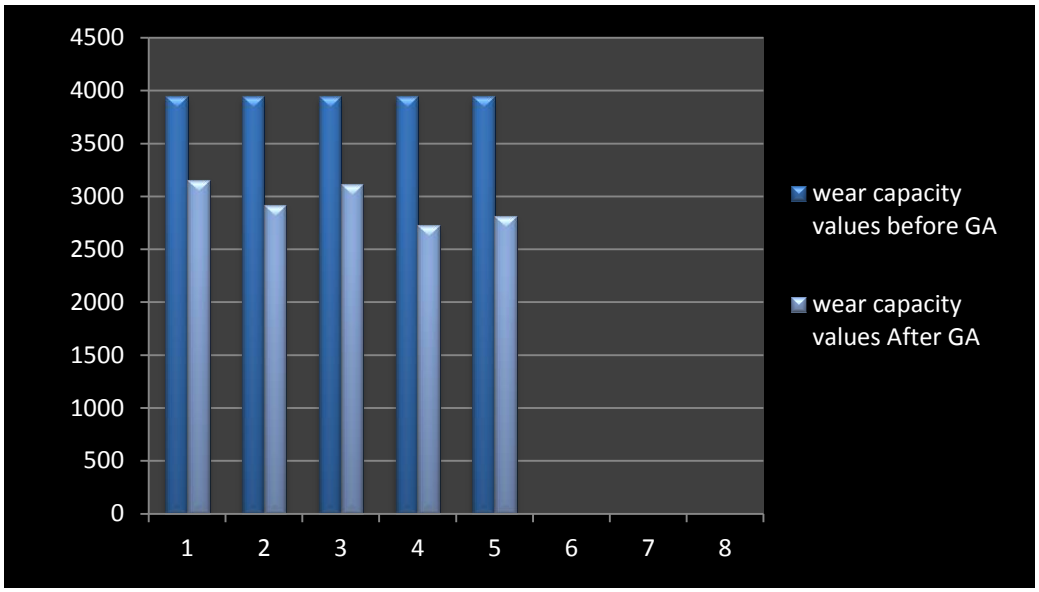

Figure2 - Graph showing the variation of required wear capacity and output of Genetic Algorithm (GA)

Table **2 -** Comparison values of wear capacity & Objective Function, Which are obtained actually and by using Genetic Algorithm

S.No	Wear Capacity	
	Before GA	After GA
1	3943.04	3154.46
2	3943.04	2912.92
3	3943.04	3113.44
4	3943.04	2722.01
5	3943.04	2812.67

V. CONCLUSION

Theoretical analysis was conducted on a worm and worm gear based on performance where SVM prediction model was developed. The developed SVM model is able to offer accurate prediction of the performance parameters for a given set of design values in comparison with actual analytical data with an error of less than 5%. Using this model, it is possible to estimate quickly the performance of the worm and worm gear design. The benefit of such a prediction model is significant reduction of processing time as well as enhanced flexibility in the design performance. If more parameters are considered over a wider range of parameters, it would certainly make the SVM model a lot more robust and thereby greatly enhance the accuracy of the Genetic Algorithm multi objective optimization in obtaining the best gear design model within the defined constraints.

REFERENCES

[1] I.W. Tsang, J.T.Y. Kwok, P.M. Cheung, "Core Vector Machines: Fast SVM Training on Very Large Data Sets", *J. Mach. Learn*. Res. 6, 363–392,2005.
[2] P.H. Chen, R.E. Fan, C.J. Lin, "A Study on SMO- Type Decomposition Methods For Support Vector Machines", *IEEE Trans. Neural Newt*. 17 (4) , 893–908, 2006.
[3] F. Chang, C.Y. Guo, X.R. Lin, C.J. Lu, "Tree Decomposition for Large-Scale SVM Problems", *J. Mach. Learn.* Res.11, 2935–2972, 2010.
[4] M. Yaman, H. Saruhan, and F. Mendi, "Power Loss Optimization of A Worm Gear Mechanism By Using Genetic Algorithm'' Technical *Education Faculty, Machine Design And Construction Department,* Turkey.
[5] V. Savsani, R.V. Rao and D.P. Vakharia, "Optimal Weight Design Of A Gear Train Using Particle Swarm Optimization And Simulated Annealing Algorithms", *Mechanism And Machine Theory*, Vol.45, Pp. 531–541, 2010.
[6] C. Gologlu and M. Zeyveli, "A genetic approach to automate preliminary design of gear drives", *Computers & Industrial Engineering*, Vol.57, Pp. 1043–1051, 2009,
[7] S. Caballero, V. Colomer and R. Romero, "Cylindrical parallel gear trains design by means of genetic optimization", *Selected Proceedings From The 12th International Congress On Project Engineering*, Pp.150-160, 2008.
[8] Y.K. Mogal and V.D. Wakchaure, , "A Multi-objective Optimization Approach for Design of Worm and Worm Wheel Based on Genetic Algorithm" *Bonfring International Journal of Man Machine Interface*, Vol.3, No.1, March 2013.
[9] V.B. Bhandari, "Design of machine elements", *Tata Mcgraw-Hill Education*, 2010.
[10] S.S. Rao, "Engineering Optimization, Theory & Practice", *New Age International Publishers*, 3rd edition, 2010.
[11] D.E. Goldberg, "Genetic Algorithms, In Search Optimization & Machine Learning", *Pearson education*, 4th edition, 2009.

AUTHORS

First Author – Mokara Bharati, M.Tech in Department of mechanical engineering, M.V.G.R College of Engineering, bharatimokara29@gmail.com.
Second Author – V.Deepika Poornima , M.Tech in Department of mechanical engineering, M.V.G.R College of Engineering, deepikapoorni@gmail.com.
Third Author - S.Jyothrimai, M.Tech in Department of mechanical engineering, M.V.G.R College of Engineering, jyothirmai.srinathu@gmail.com

Corresponding Author - Mokara Bharati, bharatimokara29@gmail.com