Optimizationof Weightof Abelt-Pulley Drive Using Alo, Gwo, Da, Fa, Fpa, Woa, Cso, Ba, Pso And Gsa

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Abstract:
Optimization methods are presently used in solve many problems in the world. Belt Drives are used to transfer rotating motion from one shaft to another shaft. In this paper weight minimization of a belt –pulley drivesis solved using ten non-traditional optimization methods.The results show that the Particle Swarm Optimization outperforms compared to the other methods.

Keywords:belt –pulley drives, weight minimization, Non-Traditional Optimization.

1. INTRODUCTION

By the means of V-belts, flat beltsor ropes power is transmitted one shaftto another by the use of pulleys.Moderate amount of power is transmitted by stepped flat belt drives andis used by workshops andfactories.The weight of pulley generally acts on the bearing and shaft. The failure of the shaft is due to weight of the pulleys commonly. Weight minimization of flat belt drive is very essentialto prevent the bearing and shaft failure [3].

2.1. FORMULATION OF PROBLEM

The design of the belt –pulley drivesis considered with theweight of pulleys (W_p), density of shaft material (ρ), width of the pulley (b), tangential velocity of pulley (V), belt tension in the tight side(T_1), belt tension in the loose side(T_2), diameter of the first pulley(d_1), diameter of the third pulley(d_1^1), diameter of the second pulley(d_2), diameter of the fourth pulley(d_2^1), thickness of the first pulley(t_1), thickness of the third pulley(t_1^1), thickness of the second pulley(t_2), thickness of the fourth pulley(t_2^1), speed of the first pulley(N_1), Speed of the third pulley(N_1^1), speed of the second pulley(N_2), speed of the fourth pulley(N_2^1), thickness of the belt(t_b) and allowable tensile stress of belt material(σ_b) [2].

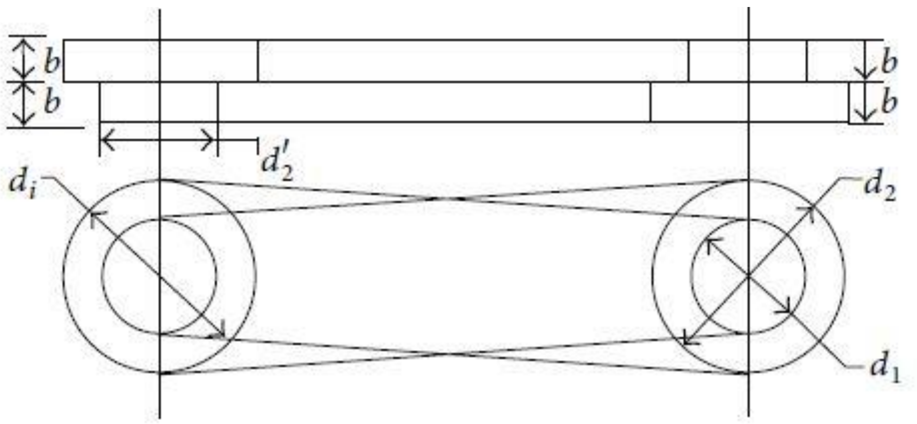

Figure1:Belt-Pulley Drive [1]

Objective Function.
The objective function is to minimize the weight of the pulley

$$W_p = \pi\rho b\left[d_1t_1 + d_2t_2 + d_1^1t_1^1 + d_2^1t_2^1\right]$$
(1)

Assuming $t_1 = 0.1\,d_1$, $t_2 = 0.1\,d_2$, $t_1^1 = 0.1\,d_1^1$, $t_2^1 = 0.1\,d_2^1$, $d_1^1 = 2\,d_1$ and $d_2^1 = 0.5\,d_2$. d_1, d_2, d_1^1, and d_2^1 is replaced by N_1,N_2, N_1^1 and N_2^1 and by substituting the values we get the objective function as

$$W_p = 0.113047\,d_1^2 + 0.0028274\,d_2^2$$
(2)

2.2 CONSTANTS

N_1	1000rpm
N_2	250rpm
N_1^1	500rpm
N_2^1	500rpm
ρ	7.2×10^{-3} kg/cm^3
$\frac{T_2}{T_1}$	$\frac{1}{2}$
P	10hp
σ_b	30 kg/cm^2
t_b	1 cm

2.3 DESIGN VARIABLES

The design variables are
Diameter of the first pulley, d_1 x_1
Diameter of the second pulley,$_2$ x_2
Width of the pulley, b x_3

2.4 CONSTRAINTS

The transmitted power (P) can be represented as

$$P = \frac{(T_1 - T_2)}{75}V \qquad (3)$$

Substituting the expression for Vin the above equation, onegets

$$P = (T_1 - T_2)\,\frac{\pi d_p N_p}{75 \times 60 \times 100} \qquad (4)$$

$$P = T_1\left(1 - \frac{T_2}{T_1}\right)\frac{\pi d_p N_p}{75 \times 60 \times 100} \qquad (5)$$

Substituting the valuesof $\frac{T_2}{T_1}$ and P in (5)

$$10 = T_1\left(1 - \frac{1}{2}\right)\frac{\pi d_p N_p}{75 \times 60 \times 100} \qquad (6)$$

or

$$T_1 = \frac{286478}{d_p N_p} \qquad (7)$$

taking
$d_2N_2 < d_1N_1$,

$$T_1 < \sigma_b b t_b \qquad (8)$$

Equating (7) and (8),

$$\sigma_b b t_b \geq \frac{2864789}{d_2 N_2} \qquad (9)$$

Substituting σ_b, t_b, N_2values in the(9),

$$30b \times 1.0 \geq \frac{2864789}{d_2 250} \tag{10}$$

or

$$b \geq \frac{381.97}{d_2} \tag{11}$$

or

$$bd_2 - 381.97 \geq 0 \tag{12}$$

The first pulleydiameter is one-fourth greater than or equal topulley width given as

$$b \leq 0.25d_1 \tag{13}$$

or

$$\frac{d_1}{4b} - 1 \geq 0 \tag{14}$$

2.5Variables Bounds

The variablesranges are

$15 \leq d_1 \leq 25$,
$70 \leq d_2 \leq 80$,
$4 \leq b \leq 10$ (15)

2.6 Mathematical Formulation

The objective functionsand subjected to constraints are:

Minimize $W_p = 0.113047\, x_1^2 + 0.0028274\, x_2^2$
subject to constraints
$x_3 x_2 - 381.97 \geq 0$ (1)
$\frac{x_1}{4x_3} - 1 \geq 0$ (2)
and x_1, x_2, $x_3 \geq 0$
The ranges of the variables are:
$15 \leq x_1 \leq 25$,
$70 \leq x_2 \leq 80$,
$4 \leq x_3 \leq 10$
where x_3 is width of the pulley, b
$x_1$isdiameter of the first pulley, d_1
$x_2$isdiameter of the second pulley, d_2

The ten Non Traditional Optimization Methods used are

1. Ant Lion Optimizer
2. Grey Wolf Optimizer
3. Dragonfly Optimization Algorithm
4. Firefly Algorithm
5. Flower Pollination Algorithm
6. Whale Optimization Algorithm
7. Cat Swarm Optimization
8. Bat Algorithm
9. Particle Swarm Optimization
10. Gravitational Search Algorithm

3. COMPARATIVE RESULTS

Table 1: Comparative Resultsof 10 Non-traditional Optimization Methods

Trial No.	ALO	GWO	DA	FA	FPA	WOA	CSO	BA	PSO	GSA
d_1	17.75	17.4	18.95	15.25	21.95	21	20.45	19	18	22.6
d_2	72.3	71.2	76.1	70.25	77.5	77	77.95	74.9	72	74.05
b	5.9	8.55	7.45	4.2	8.75	8	7.45	5.9	5	5.45

Time	1.02555	1.0495	1.08965	1.00915	1.0114	1.021	1.012	1.0211	1.009	1.0061
Weight	106.4772	106.9081	105.4251	104.5433	106.5911	108.3658	109.5235	106.4079	104.3489	107.2841

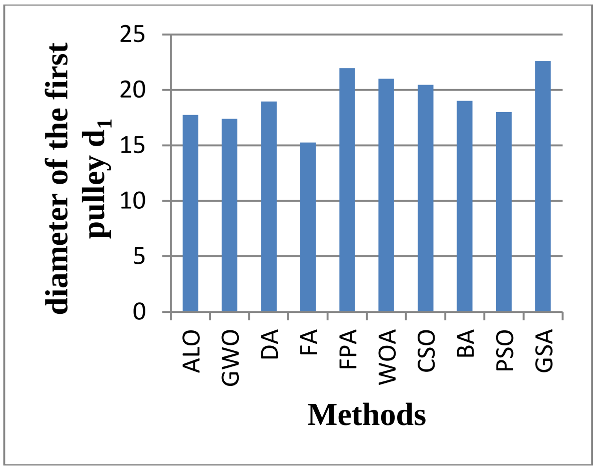

Figure 2 Results of 10 Methods for d_1

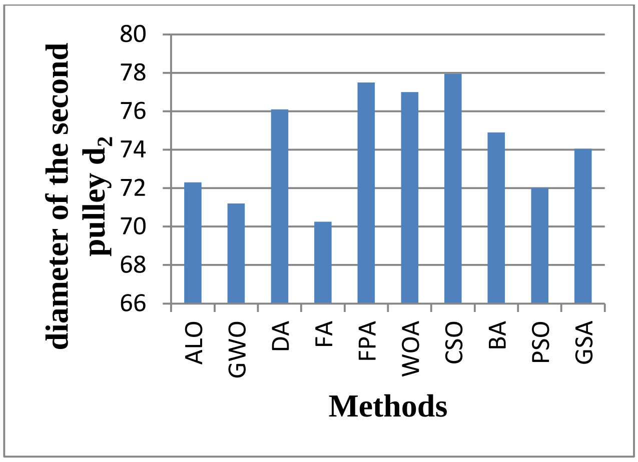

Figure 3 Results of 10 Methods ford$_2$

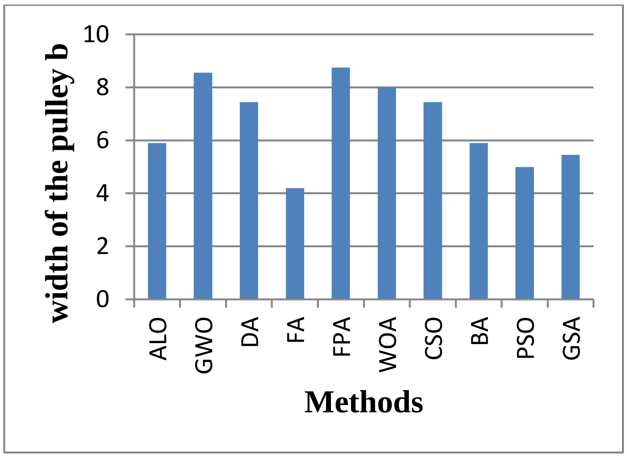

Figure 4 Results of 10 Methods forb

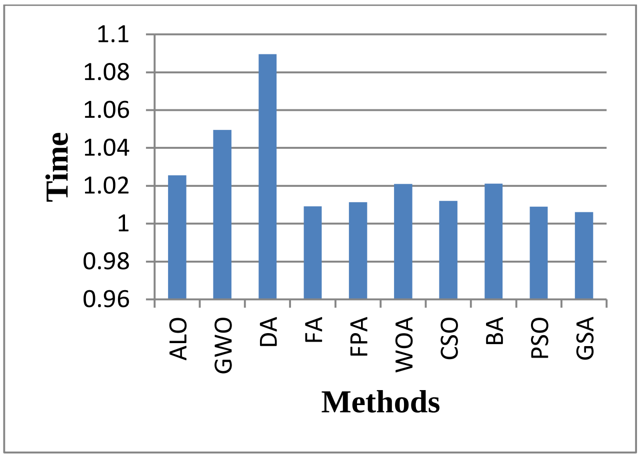

Figure 5 Results of 10 Methods for Time

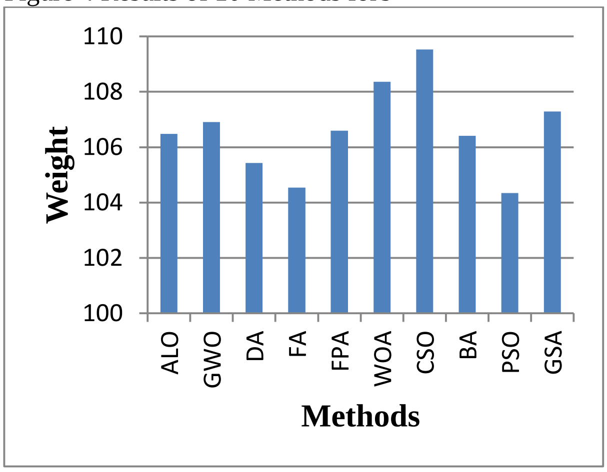

Figure 6 Results of 10 Methods forW_p

Table 2: Boundary values

	d_1(= x_1)		**d_2(= x_2)**		**b(= x_3)**	
	cm	**mm**	**cm**	**mm**	**cm**	**mm**
Upper Bound	25		80			

		250		800	10	100
Lower Bound	15	150	70	700	4	40
Optimum	18	180	72	720	5	50

4. RESULTS AND DISCUSSION

The methods are compared with three different criteria.

4.1. Consistency

The weight is minimum and consistency in the Particle Swarm Optimization (104.3489kg) when compared to Whale Optimization Algorithm (108.3658 kg).

4.2. Minimum run time

Particle Swarm Optimization (1.009 seconds) has the minimum run time compared to Cat Swarm Optimization (1.012 seconds) and Whale Optimization Algorithm (1.021 seconds).

4.3. The Simplicity of Algorithm

Particle Swarm Optimization minimizes the weight, run time and simplicity compared to Cat Swarm Optimization and Whale Optimization Algorithm. The PSO algorithm has the desirable characteristic in solving engineering problems which entail higher computational effort.

CONCLUSION

In the present work, optimization of weight of a belt-pulley drivehas been investigated.We have used MATLAB to solve the problem and the results show that Particle Swarm Optimization compared to other methods taken gives the minimum value in terms of time and weight of belt–pulley drives.

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