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RESEARCH ARTICLE

Simple and Low Cost Environmentally Friendly CASWAT-G Surface Ropeway Transportation System for Mountainous Countries

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Highlights

- CASWAT-G (Circulating Cable Supported up down Walking Technology by Using Gravity) is a surface ropeway transportation system (SRT system).
- SRT system is operated by harvested gravitational potential energy (GPE) from the users and the leg muscle energy applied by the users.
- Presented technology is useful to apply in the mountainous countries that have high possibilities potential slope places it requires.
- The system is simple, lowest cost over other transportation systems, and environmental friendly.
- The system having efficiency above 80 % can provide transportation facilities to hilly areas people as well as to touristfor recreational purposes.

Abstract

CASWAT-G (Circulating Cable Supported up down Walking Technology by Using Gravity) is a surface ropeway transportation system. There is enormous source of gravitational potential energy (GPE) in the nature which needs particular technology to use it for daily life need. Presented technology is useful to apply in the mountainous countries that have high possibilities potential slope places it requires. The system uses simple material and low number of parts which makes the technology simple and low cost. The driving forces are: harvested force from the users and leg muscle force from them. It is a pollutionless and very less destructive to natural environment technology. The simple form of prototype has the efficiency above 80% which is best even among different ropeways and is useful to apply.

Keywords: *gravitational potential energy (GPE) harvesting, CASWAT-G supported walking, environment friendly surface ropeway, leg muscle force*

Introduction

Green energies like hydro, tidal, gravitational, wind, geothermal, and solar etc. are the form of naturally found renewal energies

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sources. Among them gravitational and geothermal are non-conventional and are found day and night all the year. Saran and Ghosh [1] showed the use of GPE to produce electricity which can solve the global energy crisis as well as to protect the worst environment. In this paper we have presented the model to use GPE for providing alternative sustainable transport mean to facilitate people living in hilly countries.

About 80 % of the total land covered ranging from 60m to 8848.86m are rugged hills and series of mountains which is potential place to use GPE for mountain transportation. Difficulty to apply railways, road, airways, etc. and poor situation are mentioned in the papers [2, 3] which are challenges for quality of life in those regions. Only limited ropeways like tuin technology, gravity ropeway or modern cable cars are in operation [4, 5]. The international history of ropeway are mentioned in the papers of Hoffmann [6, 7, 8] while the Nepalese ropeway history is mentioned in the USAID report [9].

The CASWAT-G transportation system was started in Nepal and the system designed work was carried by two students Astigarraga and Fartaria at Vienna University of Technology [10, 11] to complete their master's thesises. While two students: Michailidou and Papakosta from AUTH, Greece wrote thesis [12] by experimenting on this system. Similarity of the system with funicular cableway system as a surface ropeway can be compared with the Harley- Trochimczyk, Hill Hiker and Barthelson [13, 14, 15] papers. Harvesting GPE and using of CTS is similar with funicular system while pulling action is similar to the ski lift. Use of gravity in gravity ropeways are mentioned in the papers Hada and Parikh & Lamb [16, 17]. Naniopoulos, Angelidou, et al mentioned the use of ropeway in tourism and urban transportation system [18, 19, 20]. Sources for pollutant: traffic, industry, power generation and CASWAT-G due to different emission system is show in table 1.

Table 1. sources of pollutant and their parts in the atmosphere [22]

Sources of pollutant emission	Pollutant		
	PM_{10}	NOX_2	SO_2
Traffic	60	41	14
Industry	6	8	21
Power generation	33	45	65
CASWAT-G	0	0	0

Theory and Working Principle

Situation of the component forces of a body lying on a slope angle 'θ' are *mg(sinθ)*, and *mg(cosθ)* (equal to the normal component N) and f the frictional force are shown in Fig. 1 [9].

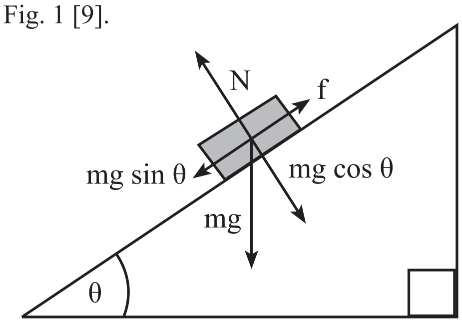

Fig 1. Component forces of a body weight lying on a slope [21]

Vector addition of forces shown in fig. 1 can be given as follows

$$mg\cos\theta = mg - m(+g)\sin\theta \quad (1)$$

Also the F_d, the downward force (μ- the coefficient of friction between the block and the surface) give

$$F_d = \mu mg\cos\theta = \mu mg(1-\sin\theta) \quad (2)$$

Similarly the upward force F_u

$$F_u = \mu mg\cos\theta = \mu mg(1+\sin\theta) \quad (3)$$

The force for plane surface F_p, is given

$$F_p = \mu mg \tag{4}$$

where:

m: the mass of the descending or ascending person (DP or AP),

g: acceleration due to gravity,

θ: the slope of the land, while using the system for walking the forces F_d, F_p, and F_u, represent the leg muscle forces (LMF) applied for downward, plane, and upward walking respectively. The efficiency (η) of the system can be given as follows [9]

$$\eta = \frac{output\ force}{input\ force} X\,100 = \frac{F_{AP}}{F_{DP}} x100 \tag{5}$$

where F_{AP}- the force used by AP

F_{DP} - the force harvested by DP

Materials and Methods

CASWAT-G and Its Working Principle

The system harvests gravity from users and along with this force and the leg muscle force, system is able to provide its transportation service to the users. The simplest form of this type of surface transportation as shown in Fig. 2 and 3 includes the following parts:

1. Two bull wheels
2. Supporting structure (SS)
3. Intermediate pulleys
4. Circulating cable (CC)
5. Body connecting cable (BCC) and
6. Users' special bel

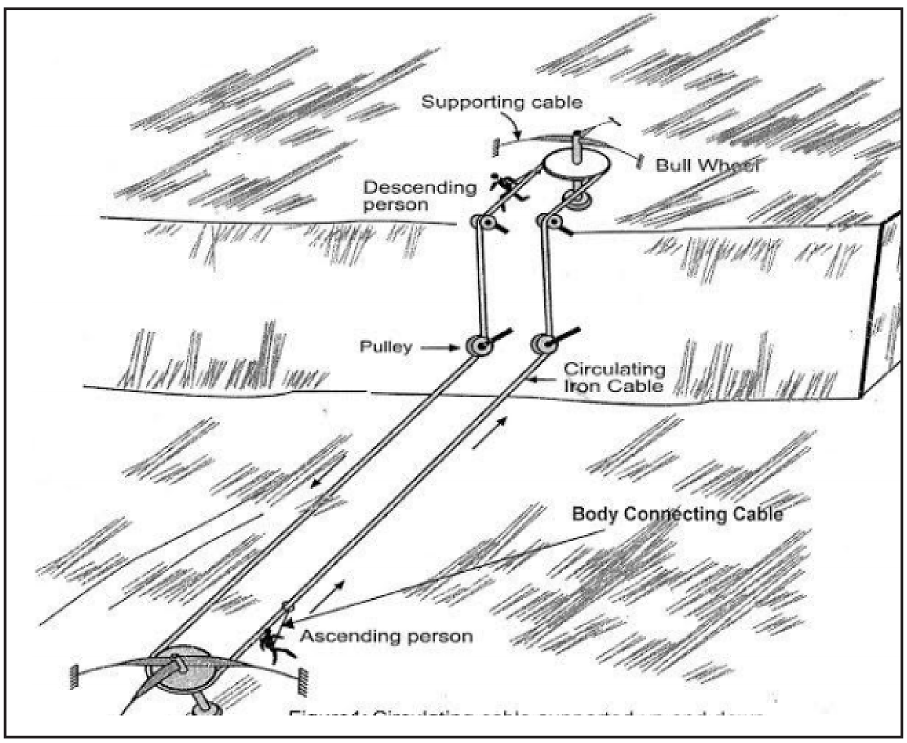

Fig 2. Schematic diagram of CASWAT-G system [9]

Fig 3. CTS prototype test at AUTH, GREECE 2015

On connecting the users by BCC to CC and taking support of it, the system harvests gravity from descending person (DP) and it is utilized to pull the ascending person (AP). While taking support, gravity balance is created among users' body weight i.e. harvested gravity of each user. For such balance condition, AP and DP with mild leg muscle force can ascend or descend very easily. Harvested and used forces by DP and AP respectively were measured by using HDWS (hanging digital weighing scale). These data were used to plot fig. 4 and fig.5 and can be used to calculate the efficiency of the CASWAT-G machine using equation 5 (not calculated here for this paper).

Results and Discussion

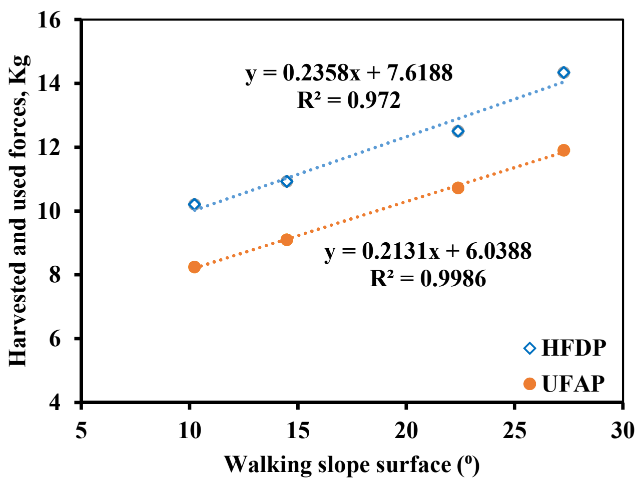

Fig 4. Harvested and used forces (Kg) by DP=45.5 kg and AP=40 kg respectively

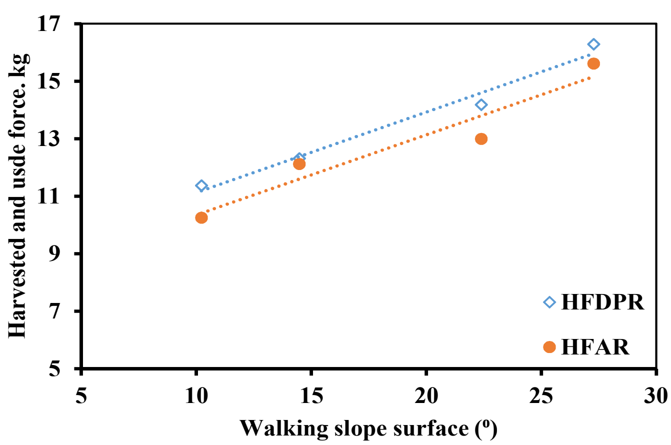

Fig 5. Harvested and used forces (Kg) for reverse case i.e. AP=45.5 kg and DP=40 kg respectively

In fig.4 and fig.5 harvested and used forces trend line are seen parallel and also seen that the harvested force line lies above the used force line i.e. harvested force is always larger than the used force which is irrespective of the magnitude of the weight of the user (i.e. weight of DP or AP).

Using data of table 1, a comparative pollution level is shown in fig. 4 in which CASWAT-G system has zero level pollution level.

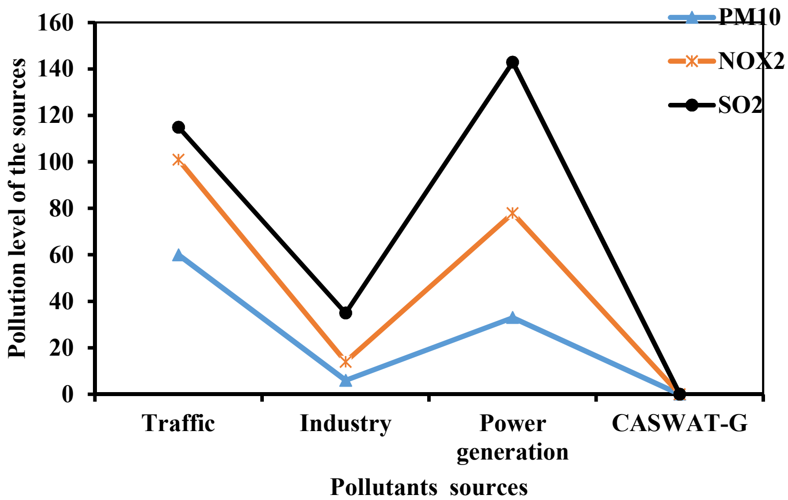

Fig 6. Situation of pollution due to CASWAT-G transportation system

Simple and low number of parts are included in constructing system. This means that constructing cost of the system as tabled in Table 1 shows its cheapness. Likewise installing cost also cheap since it can be installed to routes having 1m wide or by simple repairing the route. This saves money in constructing route, etc. Setting pulleys lower and supporting structure is very low in comparison to other transportation means since its foundation work does not require more load to resist between two pulleys. The system can be set by using hard rock or trees' stem (wherever possible) which means that it can be the cheapest ropeway transportation system (RTS). For the prototype 20m long, the cost is given in the table 1.

Table 2. Cost for 20m long CASWAT-G Transportation System

S. No.	Particular	Quantity	Cost rate (NPR)	Total (NPR)
1	Pulleys	2	3000	6000
2	Circulating rope	40m	200	8000
3	Pulley stand construction	2	5000	10000
4	Mech. Eng. work			8000
5	Commercial parts (nut bolts, peg, etc)			1000
6	Safety belt	2	500	1000
7	BCC and its connecting part	2	500	1000
8	Foundation work	2	2000	4000
9	Walking route construction	1	1000	1000
10	Total			40,000

From above calculation the total cost per km = (40000/20) x1000 = NPR 20 lakh = IC 12,50,000.

Table 3. Comparative installation cost per km for different modes of transport

S.N.	Mode of Transport	Cost (Crore)/km (IC)
1	MRTS	400
2	BRTS (single lane 50Cr)	100
3	Cable Car	25
4	CASWAT-G	0.12

Source: Kumar [23]

According to Kumar [23], MRTS, BRTS, and cable car respectively cost IC400Crore, IC100Crore, and IC25Crore and from the table 2, we can see how cheap CASWAT-G system is. Baral [18] mentioned that the efficiency of the system is above 80% which is calculated by using data (of harvested force and used force) using equation 5.

Application of the System

This system can be applied to the mountainous areas for easy up-down walking or to climb even difficult mountains as follows:

Public areas for transportation purpose, recreational purpose in tourism for trekking, climbing, tree climbing, etc. This system can also be applied as circulating boating system in the large rivers using the flow of river.

Conclusions

This system having efficiency of more than 80 % [9] is similar with funicular and ski lift systems. Because of the use of simple and less numbers of parts, the system is simple with very low cost. The system can be fitted by utilizing even strong rooted stem of the tree within the jungle without cutting trees. Only gravity and muscle forces are applied to operate the system, the emission from the system is zero. Thus the system is simple, low cost, and environmental friendly that can provide transportation facilities to hilly areas people as well as for recreational purpose to climbers that can enhance the tourism business.

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