Research Journal of Physical Sciences ISSN 2320–4796
Vol. **5(4),** 1-6, May **(2017)** *Res. J. Physical Sci.*

Harvested gravitational potential energy for mountain transportation and for calculating the efficiency of CASWAT-G machine

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Available online at: www.isca.in, www.isca.me
Received 9th March 2017, revised 3rd May 2017, accepted 4th May 2017

Abstract

CASWAT-G is a (Circulating Cable Supported up down Walking Technology by Using Gravity) surface transportation technology in which gravitational potential energy (GPE) harvested from descending user is utilized to pull ascending user up on the slope land surface and the system is somehow similar to surface ski-lift, funicular and rock climbing rope securing technique. GPE i.e. gravity of descending user and leg muscle forces of both ascending and descending user is utilized to operate the system. Beside the tests with several prototypes, especially designed CASWAT-G prototype having facility of wooden walking slope surface fitted on the iron base structure was utilized to prepare this paper. In this paper significant amount of harvested force from descending user and the utilized forces by ascending user is shown graphically. The average R-squared value and efficiency of the system were found to be 0.952 and 83.275% respectively which shows the performance is quite excellent for use. This system is simple but is efficient, safe and effective enough, cheap, and requires very comfortable effort of leg muscle force to walk up and down with negligible natural environment impact.

Keywords: Harvested, Gravitational potential energy, Mountain transportation, Efficiency, CASWAT-G machine.

Introduction

Including freely available gravitational potential energy (GPE), all source of energy is the primary and most universal measure of all kinds of work by human beings and nature[1]. There are very few technologies developed so far to use enormous source of free gravity i. e. GPE. Several CASWAT-G prototypes tests show that cable drawn transportation mean can be a successful technology to use gravity in providing transportation facility in mountain areas[2]. A ropeway is a conveyance that transports passengers or freight in carriers, along a runway consisting of one or two ropes, or rails and concrete carriageways; the hauling function is performed by one or more ropes[3,4]. Gravity is utilized to run the gravity ropeways[5]. CTS can be considered partially similar to it since the system also uses gravity. A surface lift is a means of cable transport (including funicular or inclined lifts system) and is a transportation system used to transport skiers and snow boarders where riders remain on the ground as they are pulled uphill. CTS is somehow similar to surface lift and rock climbing securing technique, particularly in towing action of the users (Figure-3)[6]. Sufficient ideas are taken from thesises - Personal transportation system for underdeveloped hilly countries[7] and Energy systems for transportation technologies[8].

CASWAT-G transportation system (CTS): Requiring much leg muscle effort or force for up and down walking against and towards the gravitational force in a slope land can be overcome by harvesting gravitational force of descending person (DP) by using CASWAT-G (Circulating Cable Supported Up Down Walking Technology by Using Gravitation) machine, Figure-1. In the machine, circulating cable (CC) acts as a hauling rope, circulates between two bull wheels fixed on the top and the base of a hill. On considering the case of two users – one walking up and the other down and connecting both users to the CC by a body connecting cable (BCC) and taking support of BCC, there will be balance of forces they harvest from their own body and frictional force in the system and it will keep them at rest. When they start walking, the harvested force of DP will pull ascending person (AP) up. No external force is required to operate the system provided there is sufficient number of descending users available. It means gravitational force of descending user and muscle force of descending as well as ascending user is utilized for easy up and down walking.

Walking up and down by using such technology arrangement is practical and comfortable for daily life use. This type of gravity harvester or transportation technology machine is simple, cheap, eco-friendly and requires minimum effort to walk up and down[9].

CASWAT-G Prototype: As shown in Figure-4, walking surface of plywood was mounted on the iron structure which has facility to move up and down to adjust for different walking slopes as demanded by the experiment. On the structure, CC loop of 3.5 meter circulates between two pulleys fitted above one meter on the stands. Two body connecting cables are attached at the extreme ends of the loop to connect two users (one from the top and the other from the base of the walking surface). The width of the walking surface is one meter. Included Figure-5 shows upper pulley, main digital weighing scale (MDWS), cable tensioner screw. Individual digital weighing scale (IDWS) connected on BCC measures harvested force from DP and used force by AP. MDWS measures the total tension of CC while cable tensioner maintains necessary tension on CC.

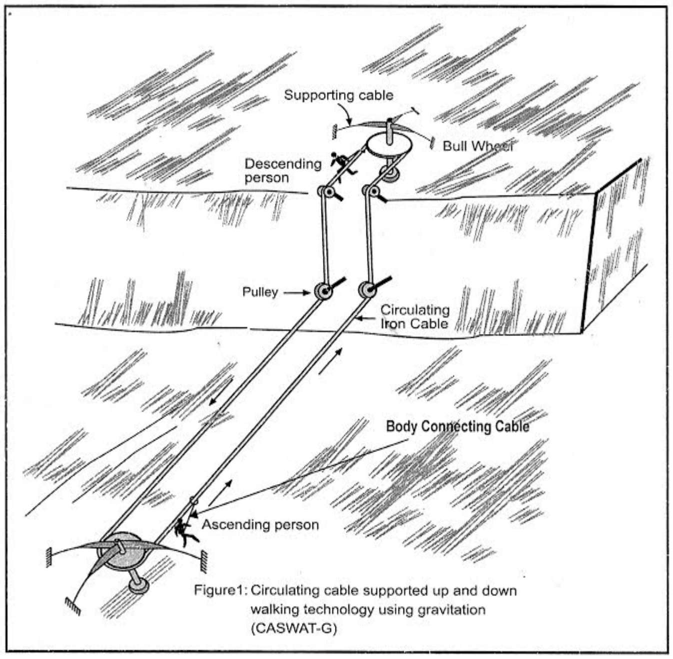

Figure-1: CASWAT-G transportation system layout.

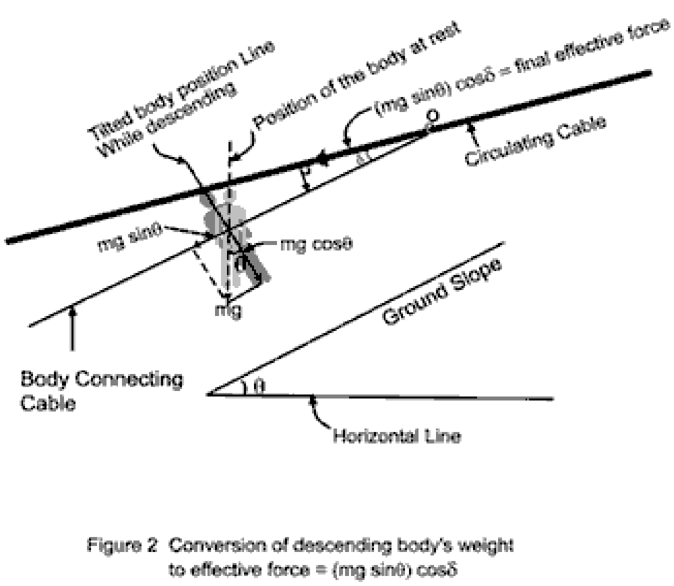

Figure-2: Sine component force of descending person's body weight.

Figure-3: Skier lifted up to the top station by the ski lift system[6].

Materials and methods

Principle and formulation: In the fundamental physics it is well known fact that the weight of the body lying on a slope land splits into two components i.e. cosine component force that acts normal to the land surface and sine component force that acts parallel to the land surface.

Exactly same thing will be the splitting case of the weight of users walking up and down on the slope land of a mountain while using CASWAT-G transportation system. Sine component forces that act along BCC on both sides users are harvested by users and these forces balance each other while taking support of CC and users feel reduced body weight due to cosine component only which acts along the users' leg. In such reduced gravity balance walking, users find even much easier than walking on the plane land surface.

From fundamental physics, theoretical formula of the force harvested from DP or AP is given by

$$F = mg\, Sin\theta\, Cos\delta \tag{1}$$

m - mass of AP or DP, g- acceleration due to gravity, θ - angle of the land slope (equal to the natural leaning angle of user) and the angle δ made by BCC with CC which for ordinary purpose can be neglected for system with long flexible rope. CTS is a gravity balance transportation system and so considering the system without friction, the gravity balance equation would look like as follows:

$$m_1 g \sin\theta_1 = m_2 g \sin\theta_2 \tag{2}$$

However there is friction in the system and if AP and DP share the total static friction F_{rs}, the above gravity balance equation would look like as follows:

$$m_1 g \sin\theta_1 - F_{rs1} = m_2 g \sin\theta_2 + F_{rs2} \quad (3)$$

The case when DP is pulling AP during walking by taking support of circulating cable (CC), the force transferred to CC from his body will be the total of forces of the force utilized to pull AP up and the force applied to overcome the total force of friction of the system, i.e. $F_{rs} = F_{rs1} + F_{rs2} = \mu(m_1 g \sin\theta_1 + m_2 g \sin\theta_2)_s$ of the system under static friction (μ-the coefficient of friction of pulley) due to masses m_1 and m_2 and equation would look like as follows:

$$m_1 g \sin\theta_1 = m_2 g \sin\theta_2 + (F_{rs1} + F_{rs2}) \quad (4)$$

While in motion the equation would look like as follows:

$$m_1 g \sin\theta_1 = \frac{1}{2h} m_2 g \sin\theta_2 \, v^2 + F_{rd} \quad (5)$$

Where: ν - the speed of the system, $F_{rd} = F_{rd1} + F_{rd2} = \mu(m_1 g \sin\theta_1 + m_2 g \sin\theta_2)_d$ - total dynamic force of friction due to masses m_1 and m_2 and h - the height through which DP descends vertically.

Working with the prototype: At least six different prototypes of CASWAT-G Models were designed, constructed, installed and tested in Nepal and two in Thessaloniki, Greece and one in Vienna, Austria. The latest prototype as shown in Figure-3 is utilized for preparing this paper. Two users of a given weight were selected to walk on the plywood surface of three meters (enough for five paces) in length mounted on the iron structure. DP from upper point and AP from down point were connected to both sides of CC by BCCs. Users in this experiment as well as previous experiments with other prototypes were asked whether the walking up and down were easy. Side by side harvested and used forces from all downward and upwards walking cases were tabulated respectively. Weight of each user and angle of walking surface was recorded. Graph of walking surface slop (WSS) versus harvested force from DP, WSS versus used force by AP and WSS versus percentage force of DPs were drawn as shown in Figures- 5, 6, and 7. Efficiency of the system was calculated which is shown in the following Table-1.

Results and discussion

Results: From the test and experiences of all the volunteers of Nepal and Europe who took part in walking up and down by using the prototype found easy walking. Graph of WSS versus harvested force from DP and used force by AP shows similar pattern i.e. almost parallel (Figure-5 and 6) in which harvested force increases with the increasing of WSS. Figure-5 also show that harvested gravitational force from DP of weight 64.5 kg is larger than used force measured with DP of weight 55.5kg. Same fact applies for the reverse case i.e. harvested force from DP of weight 55.5kg is larger than the force used by AP of weight 64.5kg (Figure-6). Both charts show that harvested force from DP is larger than the force used by AP which is irrespective of the weight of DP.

Figure-7 shows the percentage harvested force of respective weights of users for both cases of DP of weight 64.5 kg and 55.5 kg. In the chart the percentage harvested force increases with the increase of WSS. Trend line shows that straight line having large slope for heaver weight lies above the line with less weight with less slope of users.

(a) (b)

Figure-4: CASWAT-G Transportation System prototypes: (a) a prototype fitted on the wood walking surface. (b) Upper pulley with main digital weighing scale (MDWS) and cable tensioner.

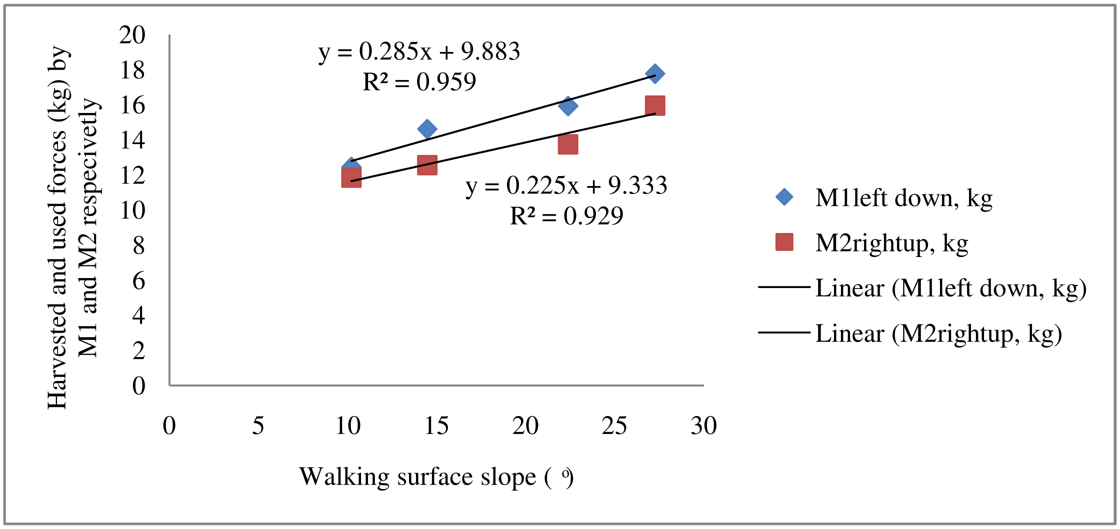

Figure-5: Walking surface slope vs harvested and used forces by users with M1 left down and M2 right up walking respectively.

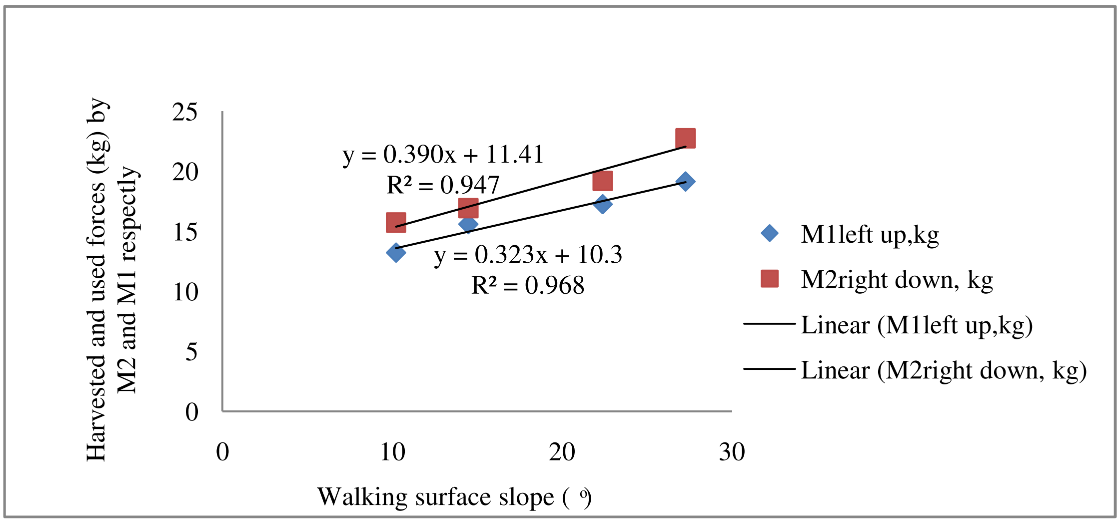

Figure-6: Walking surface slope vs harvested and used forces by users with M2 right down and M1 left up walking respectively.

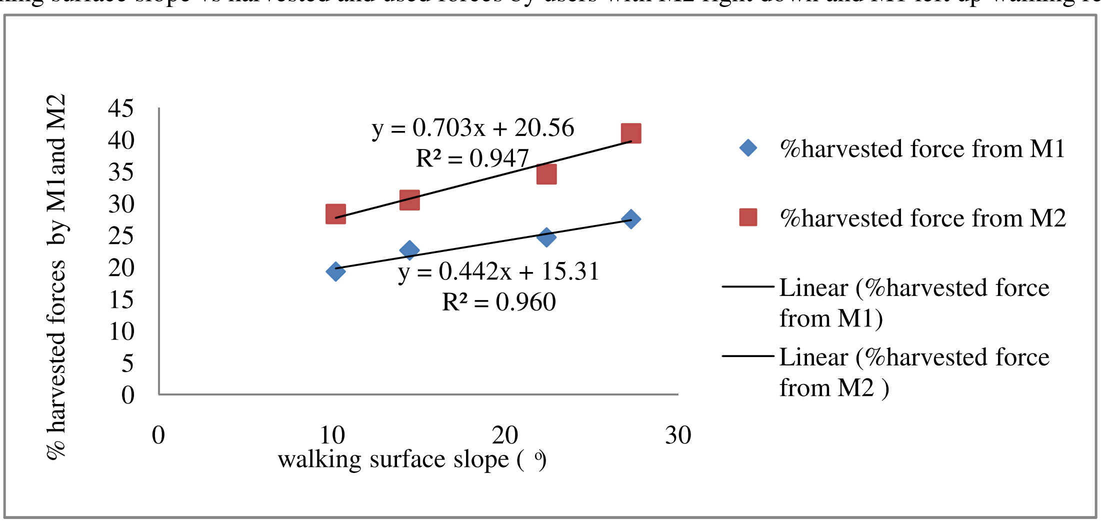

Figure-7: Walking surface slope (°) vs % harvested forces by both users M1 and M2 (walking down).

Table-1: Harvested forces are M1left down and M2right down from DP while used forces are M1left up and M2right up by AP.

surf. slope (°)	Tminimum, Kg	M1left down, kg	M1left up, kg	M2right up, kg	M2right down, kg	Efficiency (%)
10.22	33.95	12.45	13.22	11.85	15.75	89.63691
14.48	45.27	14.61	15.59	12.56	16.95	80.56446
22.39	53.22	15.92	17.26	13.74	19.21	79.60603
27.27	59.12	17.76	19.15	15.95	22.75	83.28982
						Mean, η=83.275

The percentage efficiency (Table-1) of the system for each case was calculated by using the fundamental mathematical relation of physics, i. e., η = (out put force / input force) x 100. The whole calculated efficiencies as well average efficiency of the system are shown in Table-1 which shows that almost all cases show that it is above 80 %.

Discussion: A part of the weight as sine component force of both users is transferred to CC and this makes feel user feet lighter. This is a kind of losing weight by users while using the system. In addition, force harvested from DP is utilized to pull AP up and it eases walking up for AP much easier. Also by losing weight while using the system, DP also feels easy descend. Harvested gravitational force by users means loosing of weight by users as shown by table 1. Same percentage weight lost by descending user is utilized to pull respective ascending user while using the system. The harvested force from DP in figures 5 and 6 seen larger than the force utilized by DP is due to the fact that a part of force is utilized to overcome the force of friction (not shown in this article) in the system. This means that the harvested force is equal to the utilized force plus the force of friction.

Conclusion

Gravitational force i.e. gravity or gravitational potential energy can be harvested from the descending users by utilizing the CASWAT-G transportation system and the harvested force can be used in pulling ascending user up. The high efficient system eases the walking of both the ascending as well as descending user on the slope walking surface. The information collected from many other prototypes along with this test proves the high utility fact for implementing such system in providing rural mountain alternative transportation mean in a simpler and cheaper manner with less environmental impact and by using minimum leg muscle force.

Acknowledgments

I highly acknowledge and grateful to Prof. Dr. J.J. Nakarki (Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal) for becoming guide of this research project. Special acknowledgment goes to Prof. Dr. K. Hoffmann and Prof. G. Kartnig (Vienna University of technology Austria) for becoming guide and encouraging and supporting CASWAT-G concept as a Ph.D. project. I am very much grateful to Prof. Dr. C. B. Joshi for his valuable suggestions and encouragement during the development of CASWAT-G system (Department of Mechanical Engineering, Institute of Engineering, Pulchok, Nepal). I am grateful to Prof. Dr. P. Seferlis (Mech. Eng. Dept., Aristotle University of Thessaloniki, Greece. Finally I would like to thank many volunteers who took part in experiencing the easy up-down walking by using CASWAT-G model during its test. I thank to Nepal Academy of Science and Technology, Nepal and ERASMUS MUNDUS Mobility Program for providing me partial funding and scholarship for this project.

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