



AENSI Journals

Journal of Applied Science and Agriculture

ISSN 1816-9112

Journal home page: www.aensiweb.com/jasa/index.html



## Design and Development of a Conveyor Belt Lift with Tractor P.T.O. as Prime Mover

<sup>1</sup>Ahmad Soheili, <sup>1</sup>Shapour Jahedi Rad, <sup>1</sup>Seyed Farhad Mousavi, <sup>1</sup>Mojtaba Bavand Pour, <sup>1</sup>Ebrahim Ebrahimi

<sup>1</sup>Assistant Professor, Department of Agricultural Machinery., College of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.

<sup>2</sup>Faculty Member (Full Time), Agricultural Machinery Dept., Payam-e Nour University. Iran.

<sup>3</sup>Ph.D. Student in Biosystem Mechanics, International Campus, Ferdowsi University, Mashad, Iran.

<sup>4</sup>M.Sc. in Mechanical Engineering, Instructor of Kermanshah Technical & Vocational Teaching organization, Iran.

<sup>5</sup>Assistant Professor, Department of Agricultural Machinery., College of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.

### ARTICLE INFO

#### Article history:

Received 17 December 2013

Received in revised form 19

February 2014

Accepted 26 February 2014

Available online 8 April 2014

#### Keywords:

Belt lift (elevator) Belt conveyor

Variable inclination PTO prime mover

Mobile lift (elevator)

### ABSTRACT

Electrical conveyor belt lifts (elevators) are generally used for loading and transferring industrial and agricultural products. However, electrical conveyors must have ready access to an electricity distribution system, and at distant farms it is not easy to provide such access. Moreover, conventional electrical conveyors are not mobile and can perform loading operations only at a constant height. For these reasons, the authors recognized that there was a need for designing an inclined conveyor belt lift with variable (adjustable) loading/discharging height. The advantages of the proposed system include the following: replacement of electrical power with mechanical power in field applications, reduced power consumption as well as manpower during critical working periods, optimal use of tractor power, reduced loading/unloading time, and reduced mechanical damage to sensitive products during loading/unloading operations. During operation, the proposed conveyor belt acts normal to the longitudinal tractor axis, while the tractor P.T.O. transfers power to the gearbox of the conveyor system. The conveyor system angle of inclination (gradient) can be adjusted through a hydraulic cylinder actuated by the hydraulic output of the tractor. The linear velocity of the conveyor is adjusted through a pulley carrying wedge-shaped belts. The proposed conveyor belt power is 5 hp, but it can also be actuated through mechanical/electrical motors with lower horse powers.

© 2014 AENSI Publisher All rights reserved.

**To Cite This Article:** Ahmad Soheili, Shapour Jahedi Rad, Seyed Farhad Mousavi, Mojtaba Bavand Pour, Ebrahim Ebrahimi., Design and Development of a Conveyor Belt Lift with Tractor P.T.O. as Prime Mover. *J. Appl. Sci. & Agric.*, 9(3): 1193-1200, 2014

## INTRODUCTION

Conveyor belts are among the most widely applied transfer mechanisms. Fixed electrical lifts (hoists) are currently used in agricultural and industrial units. Due to their high versatility, conveyor belts are also used in field applications. Since electricity is scarcely readily available for operating conveyor belts in field applications, designers have turned to mechanical means to provide power for these devices. As a result, tractor P.T.O. prime movers for operating conveyor belt lifts are preferable to electricity.

In 1960, the first tractor-mounted (tractor-back) conveyors were built. These conveyor belt lifts were usually operated via a chain-sprocket mechanism (consisting of one chain and two sprockets). In one example, by coupling the conveyor lift to the P.T.O. of a tractor, power was transferred to the chain-sprocket mechanism for driving the conveyor. At the time, the drive shaft had no protective sheath or cover, nor did it have freedom of movement in the horizontal plane. Moreover, the chain and sprockets were not protected. These early conveyors were mostly used for transferring forage into the storehouse for feeding animals (Kulweic, 1985).

In another design, conveyor dimensions were determined by product type, container type, and the guiding system used for gathering the products. The first model (9 meters long and 40 centimeters wide) was fitted with a conveyor belt which greatly facilitated the related agricultural operations. In the second model which was considered a long conveyor system, the horizontal section was 18 meters long, and the width of each conveyor cell was 70 cm, making it possible for the cells to carry 10 rows of picked plants. This conveyor system was controlled by the diesel engine of a vehicle system guided and controlled independently by the operator through driving the wheels and shifting gears (changing speeds). These two conveyor models were commercially built and implemented (Daniel *et al.*, 2004).

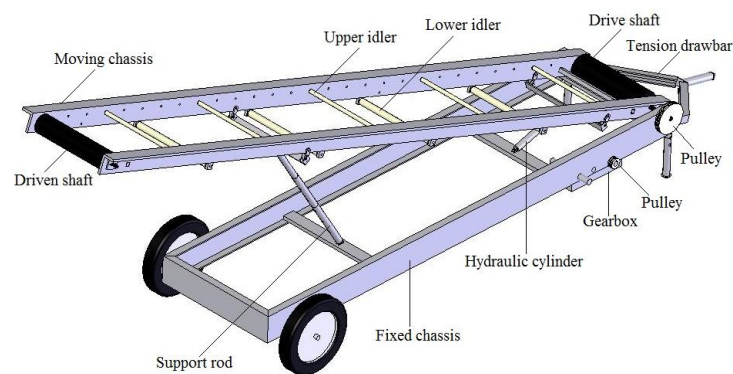
**Corresponding Author:** Ahmad Soheili, Assistant Professor, Department of Agricultural Machinery., College of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.  
E-mail: Soheili2008@gmail.com

In general, the purpose of designing the conveyor system are as follows: using mechanical instead of electrical power in seasonal field applications and in remote places in particular; reducing workforce at critical working times; replacing manpower with machine power for transportation, thus bringing down work severity for workers; utilizing optimal tractor power in agricultural, industrial, and service sectors, reducing loading/unloading time, and reducing damage to those products that should retain their physical and mechanical properties.

The proposed conveyor system can be operated with the P.T.O. available from ordinary tractors used in Iran, and can be carried by pulling. This conveyor lift can load/unload packaged products onto/from carrier vehicles like trucks and trailers. Therefore, building this conveyor lift system is economically and technically justifiable.

## MATERIALS AND METHODS

The various parts of the conveyor were selected and their respective dimensions determined once the necessary calculations had been duly performed and the required design data obtained. Fig. 1 shows the system components and their respective elements (the conveyor belt is not shown).

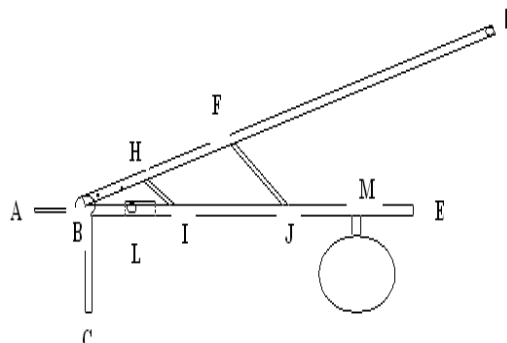


**Fig. 1:** The conveyor belt lifts components

The conveyor height depends on the moving chassis length, material, belt shape, and specific weight of the carried materials. The chassis span is equal to  $B = (b+10)$ , where  $b$  is the belt width. The belt displacement on the shaft on either side equals 5 cm.

If the length of each package is  $c$ , then there will be  $n = L/C$  packages on the moving chassis at full load when the belt is fully loaded with packages. Therefore, in the static position, the total load acting on the chassis will be  $M = n \times m$ , where  $L$  is the moving chassis length and  $m$  is the mass of one package. Of course, in practice the packages never fill out the conveyor belt completely. Nevertheless, for designing purposes, the maximum loading condition must be observed.

The schematic figure of the conveyor system, as well as its main parts, is shown in Fig. 2. In this figure, AB represents the tension draw bar, BC is the balance base for the fixed chassis, BD is the moving chassis, HI is the lifting jack, FJ is the rod holding the moving chassis, M shows the axle, and L is the gearbox.



**Fig. 2:** Schematic of the Side View of the Lifting Conveyor Belt

Designing the Moving (Mobile) Chassis

Longitudinally, the body of the moving chassis consists of two similar symmetrical halves between which on either end lie the mover and moving shafts the upper and lower idlers, and the coupler links. The length of the moving chassis as well as its cross section dimensions depend on the conveyor belt coefficient of friction, the location of the jack between the fixed and the moving chassis, transfer height of the packaged material, the amount of load acting on the system, and the location of the system's center of gravity.

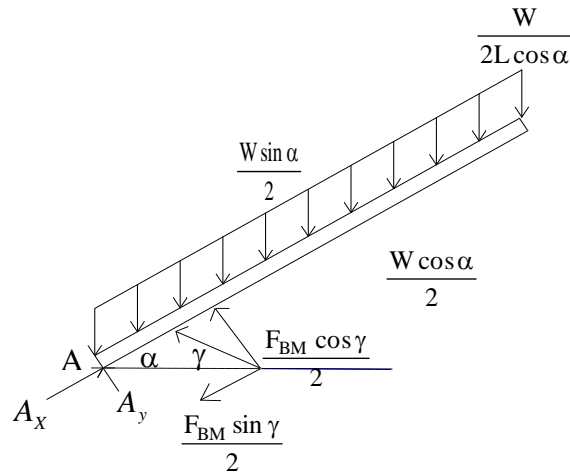


Fig. 3: Schematic of the Moving Chassis and Lifting Jack Side View

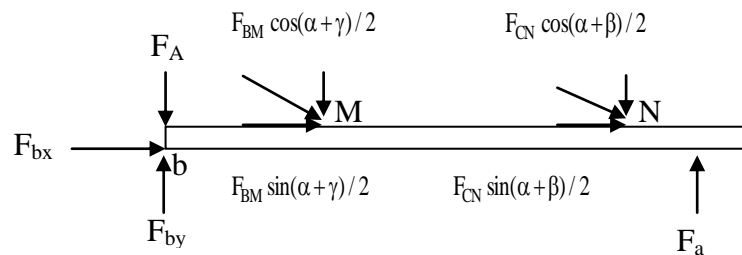


Fig. 4: Forces Acting on the Longitudinal Profile of the Fixed Chassis

From Fig. 3, we obtain the following relation:

$$F_{BM} = \frac{W_T \cos \alpha \times L}{2 \cos \gamma \times l_j} \tag{1}$$

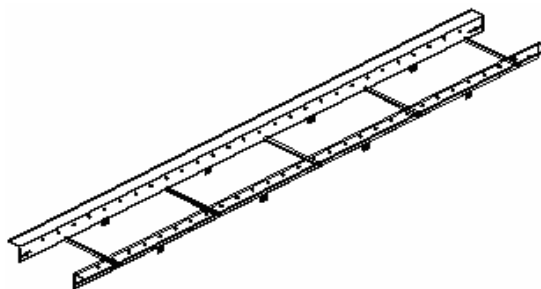


Fig. 5: The Isometric View of the Moving Chassis

where  $W_T$  is the weight of the moving chassis components, the parts assembled onto the chassis (e.g. belt, drive shaft, driven shaft, and upper idler), and the applied load.

$$F_A = \sqrt{(A_x)^2 + (A_y)^2} \tag{2}$$

$$M = A_y x + \left(\frac{F_{BM}}{2}\right) \cos \gamma (x - l_j) - \frac{W}{2} \cos \alpha \times x^2 \quad (3)$$

#### Designing the Fixed Chassis:

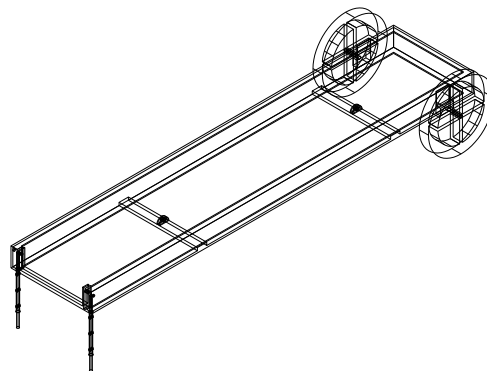
Designing the fixed chassis is based on force exerted by the lifting jack as well as the moving chassis support rod. During loading, the fixed chassis is supported by two components: 1) the wheel axle of the system, and 2) the supports placed on the other side of the chassis for maintaining balance during operation (Fig. 4).

By applying the equilibrium of forces equation along x and y axes, we obtain the force applied to the chassis base as follows (Dibaie, 1999):

$$F_B = \sqrt{(F_{b_x})^2 + (F_{b_y})^2} \quad (4)$$

The axle force is calculated as:

$$F_a = \frac{\frac{F_{BM}}{2} \cos(\alpha + \gamma) l_1 - \frac{W_c}{2} \left(\frac{A + 2a}{2}\right)}{(A + 2a - l_2)} \quad (5)$$



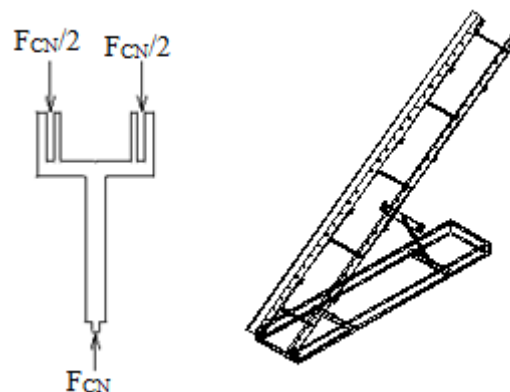
**Fig. 6:** Schematic of the Fixed Chassis with the Height-Adjusting Rod and its Connection to the Moving Chassis

where  $W_c$  is the fixed chassis height,  $l_1$  is the distance between the jack fulcrum on the fixed chassis to the fixed and moving chassis point of attachment,  $l_2$  is the distance from the axle to the fixed chassis endpoint, and  $A + 2a$  is the chassis length.

#### Designing the Moving Chassis Retaining Rod

The lower end of the retaining rod is hinged to the fixed chassis and its upper end is joint-pinned to the moving chassis. The retaining rod must be designed so as to stay clear from the return path of the belt (under the moving chassis) which continues to the rear of the system.

$$F_{CN} = \frac{W_T \cos \alpha \times L}{2b' \cos \beta} \quad (6)$$



**Fig. 7:** Free Body Diagram of the Retainer Rod and its Position between the Chassis

where WT is the total weight, FCN is the force applied to the moving chassis, and b' is the normal distance from the attachment point of the two chassis to the moving chassis retaining rod.

*Designing the Drive Shaft:*

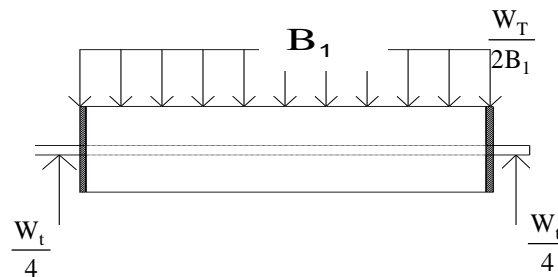
The drive shaft must tolerate the torsion resulting from rotation of the pulley and the V-shape drive belt. The following relation can be obtained in the dynamic case for the drive shaft and its inner shaft:

$$\frac{16}{\pi d^3} \sqrt{(C_m M_{max})^2 + (C_t T)^2} = \frac{\tau_y}{n} = \frac{0.5 \times \sigma_y}{n} \tag{7}$$

The diameter of the hollow drive shaft is obtained as follows:

$$D = \frac{360P}{p \times \pi \times \alpha \times B} \tag{8}$$

where P is the pressure exerted from the belt to the cylinder (from 1600 to 2000 kPa/m<sup>2</sup>), p is the total peripheral force (expressed in newtons), α is the angle between the belt angle and the cylinder centerline (in degrees), and B is the belt width (in meters).



**Fig. 8:** Free Body Diagram of the Drive Shaft

*Designing the Lifting Jack:*

The lifting jack is used for adjusting the inclination angle (gradient) of the moving chassis, and is driven by the tractor hydraulic output rod. The jack is designed for lifting the system when it is loaded to its maximum capacity as follows:

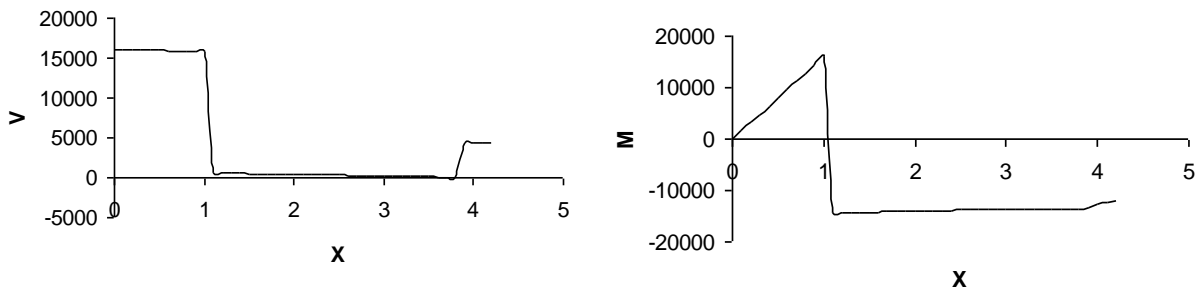
$$D = \frac{W_T \cos \alpha \times L}{2 \cos \gamma \times l_j} \tag{9}$$

where l<sub>j</sub> is the length of the line drawn from the attachment point between the two chassis to the jack force line of action.

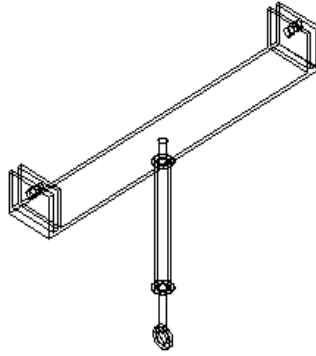
*Designing the Conveyor Belt:*

To increase the coefficient of friction between the load and the conveyor belt, knobs and indentations are formed into the belt surface the shapes of which depend on the kind of bulk material conveyed on the belt. Individual commodities (e.g. packages, units, etc.) are often carried on conveyor belts with rough wavy surfaces.

Belts with a serrated profile can increase the conveyor gradient from 45 to 60 degrees. In flat belts, the cross sectional area of the belt is obtained from



**Fig. 9:** Shearing Force and Bending Moment Diagrams of the Fixed Chassis



**Fig. 10:** The Isometric View of the Moving Chassis Retainer Rod

Equation 10. The fatigue stress developed in the belt is calculated from Equation 11 (Editors' Group, 2001):

$$S = \frac{T'}{\sigma_b} \quad (10)$$

$$\sigma' = \frac{\rho_b V^2}{g} \quad (11)$$

where  $T'$  is the tight side tension in the belt,  $\sigma_b$  is the normal stress in the belt,  $\sigma'$  is the fatigue stress in the belt,  $\rho_b$  is the belt specific weight, and  $v$  is the linear velocity of the belt. At low flat belt speeds, the centrifugal



**Fig. 11:** A view of the Conveyor Belt Lift (the conveyor belt is not shown)

effects are ignored in the calculations. Moreover, the tight and slack tensions in the belt are calculated from the following relations:

$$\frac{T'}{t'} = k'' e^{f\alpha} \quad (12)$$

$$T' = \frac{k'' e^{f\alpha}}{(k'' e^{f\alpha} - 1)} \quad (13)$$

$$t' = \frac{F}{(k'' e^{f\alpha} - 1)} \quad (14)$$

where  $k''$  defines the non-slip condition for flexible belts,  $T'$  is the tight side tension, and  $t'$  is the slack side tension in the belt.

The cross sectional area of the belt is obtained from the following formula (Zarei Pour, 2003):

$$A = bs = \frac{F_N}{\sigma_N} = \frac{750P}{\sigma_N \times v} \quad (15)$$

And the actuating force is obtained as (Zarei Pour, 2003):

$$N' = \frac{QL}{100} + \frac{QH}{270} \quad (16)$$

where  $v$  is the linear speed of the belt (m/s),  $\sigma_N$  is the normal stress in the belt ( $N/m^2$ ),  $L$  is the belt length, and  $H$  is the load carrying height (m). The load carried on the conveyor belt is calculated as (Zarei Pour, 2003):

$$Q = (0.9B - 0.05)^2 v \times \gamma \times k \quad (17)$$

where  $Q$  is the carried load (ton/h),  $B$  is the belt width (m),  $V$  is the linear speed of the belt (m/s),  $\gamma$  is the specific weight of the conveyed material (ton/m<sup>3</sup>), and  $k$  is the dryness coefficient of the carried load (1400 for dry loads and 2000 for loads containing moisture).

### Conclusion

#### Moving Chassis:

The moving chassis calculations were performed by considering a maximum force of  $F_{BM} = 68273 N$  exerted on the jack. Based on the section modulus of  $S = 9.11 \times 10^4 \text{ mm}^4$  obtained for one half of the chassis, an L shaped angle of size 19 x 102 x L152 was chosen from the standard design tables (Vali Nezhad, 1998). Subsequently, by placing the retaining rod under the chassis, we obtained the moving chassis dimensions as 76 x 12.7 x L127 (an L-shaped angle profile), and the force exerted on the other chassis links, namely, the connecting pins and the retaining rod (i.e. the force exerted on each U-shaped edge of the retaining rod) as

$$\frac{F_{CN}}{2} = 18876N .$$

#### Fixed Chassis

In the case when the lifting jack alone exerted force on the fixed chassis (i.e. the jack alone acted under the moving chassis), the exerted force was obtained as  $F_A = 32032 N$  and the fixed chassis section profile was taken as a C-shaped channel with dimensions C200 x 20.5 (Vali Nezhad, 1998). Fig. 9 shows the shearing force and bending moment diagrams obtained for the fixed chassis.

#### Moving Chassis Retainer Rod

The isometric perspective of the moving chassis retaining rod is shown in Fig. 10, and the values of designed parameters for the retaining rod are presented in Table 1.

**Table 1:** The Calculated Design Parameters for the Retaining Rod

Parameter	Calculated Value
Total weight of the moving chassis with load	12,000 N
Minimum retaining rod angle	5 degrees
U-shaped part length	0.75 m
Retaining rod positioning angle	71 degrees
Moving chassis length	6 m
Yield stress of the retaining rod	290 MPa

#### Drive Shaft:

In Table 2, design parameters for the drive shaft, and in Fig. 11, a view of the designed conveyor belt are shown.

**Table 2:** Design Parameters for the Drive Shaft

Parameter	Calculated Value
Weight of the conveyor belt and its load	5946 N
Distance between support ball bearing and the shaft	0.1 m
Length of shaft pipe	0.65 m
Shaft outer diameter	0.2 m
Bending moment coefficient	1.5
Torsional moment coefficient	1
Drive shaft cross sectional area	25.6 mm <sup>2</sup>
Torque exerted on the drive shaft	210 N.m

## RESULTS AND DISCUSSION

A normal linear velocity of 20 m/min was chosen for the lift conveyor belt, which is a proper speed due to the fact that the agricultural products are least damaged at this speed and there is enough time for their correct arrangement.

The wedge shaped belts serve the purpose of reducing speed as well as provide speed variations for the system. However, they serve the additional purpose of acting as a safety clutch. Moreover, since the electric motor in electrical conveyors can operate in both CW and CCW directions, the lift belt conveyor can be used for unloading materials/products as well. As the direction of rotation of the tractor power delivering shaft always remains constant, a gearbox must be designed for reversing the conveyor belt movement. For this reason, the tractor power delivering input shaft to the gearbox is considered on both sides of the system so as to accomplish this working demand.

The required power for operating the belt depends on the height of the moving chassis end from the ground. Considering a safety factor of 2.5 for most components, a minimum power of 5 hp from the power generated by the tractor would be needed for the conveyor. However, due to the high safety factors considered for the system, it would be possible to actuate the system at lower powers as well.

The working capacity of the system is approximately 11 ton/h. Increasing the coefficient of friction and using serrated belts would reduce the length of the moving chassis, thus making it possible to adjust the system gradient by displacing the lifting jack relative to the mechanical jacks under the moving chassis. In this way, the system can be better balanced during the initial angle adjustments, and can be used even when hydraulic force is not available.

In case the tension drawbar is jointed, the initial distance between the fixed and moving chassis can be increased. This would reduce the initial height of the moving chassis from the ground during loading/unloading operations, so that transferring packages onto the conveyor could be more easily done. As the speed of the conveyor belt is reduced, the inclination angle (at increased material specific weight) is increased. However, replacing the wedge-shaped belts shall introduce variable speeds for the conveyor, making the proposed conveyor system also suitable for other applications in the industrial and service sectors.

## ACKNOWLEDGMENTS

This article was adapted from the sponsored research project entitled "Design and Construction of a P.T.O. Drive Belt Conveyor". The authors hereby express their gratitude to the Islamic Azad University, Kermanshah Branch, for providing financial support for this project.

## REFERENCES

- Daniel, J., Fonseca, Gopal Uppal and Timothy, J. Green, 2004. A Knowledge-based system for conveyor equipment selection, *Expert systems with Applications*, 26(4): 615-623.
- Dibai Nia, B., 1999. "Machine Design in Mechanical Engineering", University Publication Center.
- Editors' Biard, 2001. "Fixed Agricultural Machines", Volume 1, Technical and Professional Center (Agricultural Machinery), Educational Texts Publications.
- Kulweic, A.R., 1985. *Materials Handling Handbook*. 2nd Edition American Society of Mechanical Engineers. International Material Management Society. John Wiley & Sons, Inc. ISBN 0-471-09782-9.
- Vali Nezhad Nia, A., 2008. "Standard Tables in Machine Design", Tarah Publications.
- Zarei Pour, Gh., 1999. "Machine Design", Nasr Cultural and Scientific Publication Institute.