

DEVELOPMENT OF A COMPUTER PROGRAM FOR THE DESIGN OF AUGER CONVEYORS FOR AGRICULTURAL PRODUCTS

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ABSTRACT

The screw or auger conveyor is an important conveyor in agricultural and food processing industries. The classical approach to its analysis and design involve the determination of the type and dimensions of the pitch, capacity, screw housing, clearance, length and diameter, shaft diameter, speed of revolution, filling factor, necessary elevation, and power requirements, in addition to the design of the layout. These are done by a combination of calculation and selection from charts. After these, the torque requirement is checked against maximum allowable torque given in charts, which may require the designer to repeat the process in an iterative manner. This can be frustrating where it is done for different products and where it is necessary to consider alternative designs in order to achieve design optimization. A computer program was developed for the above processes to remove the constraints of the classical approach. The program which is iterative and menu driven, accepts relevant input data (material to be conveyed, required capacity, elevations involved, etc) and does the required calculations, selection and optimization. It then gives the user the required dimensions and parameters of the conveyor. Results of evaluation tests show that the program is efficient in the design process and saves time, especially where alternative designs are required to be produced.

1. INTRODUCTION

The screw or auger conveyor is a common conveyor in agricultural field machines and many agro-based process industries. It consists of a long-pitch, plate steel helix mounted on a shaft carried on bearings within a u-shaped trough which may be covered or uncovered depending on type of the material being conveyed. The components of a typical screw conveyor include the plate helix mounted on a shaft, both of which are housed in a trough. The shaft is mounted on bearings and is driven by an electric motor. The entire assembly can be on a horizontal plane or an

incline. The trough is equipped with material which is fed from one end and a discharge opening at the other end.

As the shaft and helix rotate, the material fed into them is moved forward by the thrust of the lower part of the helix and is discharged through the opening in the trough bottom or at the end of the trough. Where flow through the other end is restricted, the conveyor serves as a press for oil or juice extraction. The conveyor finds wide application in grinders, oil extraction machines, feeding mechanisms, mixing machines and in process industries such as rice mills, flour mills, starch mills and

confectionery industries. The design and analysis of conveyors is therefore a common exercise in such industries and in the teaching of agricultural materials handling systems [1], [2]

Classically, auger conveyor elements are designed by selection using empirical charts and tables developed through research and testing by conveyor manufacturing companies. These charts and table are used manually by the designers. The choice of chart or table is dictated by the type, condition and quantity of material being handled and the type of auger to be used. The values obtained from the charts and tables are used to select the screw pitch, capacity, clearance, length and diameter of shaft, speed of revolution and power requirement for the system. For the fact that the design procedure is executed manually, there is loss of time and so increased cost of design and analysis. Enormous time is spent in the analysis and design of screw conveyor before the construction of the final machine. In addition, evaluation of the bill of quantities for the materials to be used in the final product manufacturing is tedious. Therefore, the manual approach to design does not allow for rapid modification of designs and so optimal design is difficult to attain.

These problems can be solved by the use of computers in design. With computers, different alternative designs can be investigated to determine the effects of changes of pertinent design variables. An entire design procedure could be sequenced and a design software developed which can have any or a combination of these capabilities: material selection, drawings, analysis, size selection and design of standard components such as spring, bolt, nut, pipe, structural sections, key ways, etc. such a system is referred to as Computer Aided

Design (CAD) system [3], [4]. The computer (software) assists the Engineer by enabling him to quickly generate alternative designs which can be shown on the computer screen. It can also assist in design of building, mechanical devices, bridges, ships, aircrafts etc [5].

Their applications in agriculture and food processing are still evolving [6], [7] [8] [9],[10] [11]. Most of the commercial CAD systems are expensive and demand enormous computer space and time. The use of simple programs for analysis and selection of system components offer the engineer an efficient tool to improve on his work. A computer programs was developed by [12]for the selection and analysis of components of a bucket elevator. For auger conveyors, such a program is not in existence. When developed, it could form the basis for a bigger CAD system for materials handling equipment.

The objective of this paper is to describe a computer program which was developed for the analysis and selection of components of an auger conveyor.

2. DESCRIPTION OF THE COMPUTER PROGRAM

2.1 The Classical Approach to Conveyor System Components Selection

The parameters of the components of the conveyor that need to be selected in a design process include: shaft diameter, screw diameter, delivery rate, and operating speed. Others include screw pitch, power and torque requirements. In the classical approach, these selections are made from charts and tables.

There are four charts namely 1, 2, 3, and 4. Chart 1 is for light, free flowing and non-abrasive materials such as rice, oats and wheat. Chart 2 is for non-abrasive materials of medium weight containing fines and small

lumps such as beans, soybeans, coffee, and shelled corn. Chart 3 is for semi abrasive materials that are granular with small lumps such as dried milk, saw dust and salt. Chart 4 is for abrasive and semi abrasive material such as raw sugar and unshelled groundnut. Each of these charts shows plots of speed (rev/min) on the vertical axis and capacity (m^3/hrs) on the horizontal axis.

Thus if the desired conveyor capacity (Q) is known, and the crop or product is known, one would first decide on the chart (1-4) that best suits the product. With the capacity known, a guess is made on the shaft diameter (d) to be used. The appropriate line on the chart is then used to read off the corresponding speed of revolution (N) on the vertical axis. The filling factor ($_$) is selected from a table for the particular crop depending on whether the conveyance is horizontal or vertical. Another table for maximum torque allowable is used to obtain the inside diameter (D) of the housing. Using these parameters, the screw pitch (p) is calculated using the following equation:

$$Q = (D^2 - d^2) p N _ \quad \dots(1)$$

Next, the power required by the conveyor is calculated using the expression:

$$P = CL\rho F \quad \dots(2)$$

where P = power; L = length of conveyor; ρ = density of the production to be conveyed and F is Material Factor which is obtained from a table. Using power (P) calculated above, the required Torque (T) is calculated using the expression:

$$T = P/N \quad \dots(3)$$

This torque is cross-checked using the Table of allowable maximum torque for the size of shaft and screw chosen above. If the torque obtained above is less than that in the Table, then the design is safe. Otherwise, the calculations are repeated using a different selection. This process is continued until the

calculated torque is less than the one in the Table. The parameters obtained are then used to draw the layout of the conveyor. The selections of other components like bearings, electric motor, etc are accomplished according to standard practice. This iterative process therefore is not only tedious but requires a lot of time for an acceptable solution to be obtained.

2.2 The Computer Program for Conveyor System Components Selection

A computer program was developed for the selection of components and analysis of screw conveyors. The computer program essentially implements the procedure described for the "manual" system above in a computer. The four charts were first converted to Tables. These Tables together with the other Tables for selection of the components are saved in different Data Files in the Computer. The program then implements the procedure described above for the manual system by picking the appropriate values from the data files and using an iterative algorithm to optimize the design.

The flowchart of the computer program which was developed in Fortran is shown in Figure. 1. The Fortran source code for the omputer program is as shown in appendix. The programme starts by allowing the user to select or enter the capacity of the conveyor and the crop to be conveyed. Input and output data files are then opened. Depending on the crop in question the data file corresponding to the appropriate chart is accessed by the program and with the capacity entered by the user, the program selects the screw diameter and speed. With the information above, the screw pitch is calculated using equation (1). Power is next calculated using equation (2). Then the power obtained is used to calculate the torque using equation (3). The torque calculated is compared with the values in a

data file containing maximum allowable torques. If the design is safe, the results are printed. If it is not safe, the procedure is repeated with an appropriate decrease or increase in the size of screw selected.

The program was designed to be menu driven and interactive, making it user friendly as shown in Appendix 1.

2.3 Evaluation of the Computer Program

The computer program was evaluated by using it to carry out an analysis of some selection problems and comparing with the "manual" method of analysis. The comparison was with respect to accuracy, time of execution and ease of use.

3. RESULTS AND DISCUSSION

The program is superb in the carrying out the analysis and selection of the components of the screw conveyor. For the different scenarios tested, the computer results did not vary significantly when compared with those obtained by "manual" calculations. The difference between the two was in the time required to accomplish the task. The computer solution was obtained on the average in 1/20 of the time required for manual calculations. In addition, the occurrence of mistakes and errors was zero, unlike the manual system.

Future work in progress involves the integration of a graphics routine to enable the user develop the drawing of the screw conveyor.

4. CONCLUSION

A computer program was successfully developed for the analysis and selection of components of screw conveyors for different products. The computer solution was found to decrease the time for design significantly. The package is recommended for practicing engineers and academics interested in the use of computers for such analysis.

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APPENDIX . FORTRAN SOURCE CODE FOR EXAMPLE MATERIAL A

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PROGRAM SCREW_DESIGN
REAL B(20),C,D,E,H(20),N,P(20),Q,S(20),T(20),U,V,W,X,Y
INTEGER A(20),F,G(20),I,J,K,L,M,O(20),R(20),Z(20)
C
C CLASSIFICATION OF MATERIAL AND SELECTION OF CHART
WRITE(*,5)'CHOOSE CLASS AND CHART OF MATERIAL TO BE CONVEYED'
1 FORMAT(/)
2 FORMAT(//)
3 FORMAT(///)
4 FORMAT(4X,A)
5 FORMAT(5X,A)
8 FORMAT(8X,A)
10 FORMAT(10X,A)
12 FORMAT(12X,A)
15 FORMAT(15X,A)
18 FORMAT(18X,A)
20 FORMAT(20X,A)
22 FORMAT(22X,A)
WRITE(*,1)
WRITE(*,22)'CHART 1'
WRITE(*,*)'Light material, free flowing & non abrasive materials'
WRITE(*,*)'like cornmill, barley, oats, rice, garri, wheats,'
WRITE(*,*)'pulverized coal etc.'
WRITE(*,1)
WRITE(*,22)'CHART 2'
WRITE(*,*)'Non abrasive materials of medium weight containing'
WRITE(*,*)'fine particles and small lumps eg. beans, soybeans,'
WRITE(*,*)'shelled corn, coffee, cotton seeds etc.'

WRITE(*,1)
WRITE(*,22)'CHART 3'
WRITE(*,*)'Semi-abrasive materials that are granular with small'
WRITE(*,*)'lumps and bulk desities of 40 - 80 ib/cu.ft such as'

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WRITE(*,*)'dry cotton seed, dried milk, saw-dust, salt, etc.'
WRITE(*,1)
WRITE(*,22)'CHART 4'
WRITE(*,*)'Abrasive and semi-abrasive materials like raw sugar,'
WRITE(*,*)'unshelled groundnut/peanut, castor oil beans etc.'
WRITE(*,1)

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```
50 WRITE(*,5)'DESIGN OF AUGER CONVEYORS'
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C = 0.0
D = 0.0
E = 0.0
F = 0
G(20) = 0
H(20) = 0.0
J = 0
V = 0.0
WRITE(*,*)'ENTER 1 FOR A MATERIAL IN CHART A'
WRITE(*,*)'ENTER 2 FOR A MATERIAL IN CHART B'
WRITE(*,*)'ENTER 3 FOR A MATERIAL IN CHART C'
WRITE(*,*)'ENTER 4 FOR A MATERIAL IN CHART D'
WRITE(*,1)
READ (*,*)M
IF(M.EQ.1)THEN
Y = 0.4
GOTO 100
ELSE IF(M.EQ.2)THEN
Y = 0.4
GOTO 300
ELSE IF(M.EQ.3)THEN
Y = 0.9
GOTO 500
ELSE IF(M.EQ.4)THEN
Y = 0.7
GOTO 700
ELSE
WRITE(*,*)'INVALID ENTRY; CHOOSE VALUE FROM OPTION GIVEN'
GOTO 50
END IF

```

C

C AUGER CONVEYOR DESIGN FOR CHART A MATERIALS

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100 WRITE(*,2)
WRITE(*,4)'DESIGN OF SCREW FOR CHART A MATERIALS'
WRITE(*,*)'Enter The Desired Conveyor Capacity In m cu/s'
READ(*,*) C
WRITE(*,1)

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WRITE(*,*)'Enter The Bulk Density Of The Material In kg/m cu'
READ(*,*)D
WRITE(*,1)

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WRITE(*,*)'Enter The Desired Conveyor Length In m'
READ(*,*)E
WRITE(*,1)
110 WRITE(*,*)'Make A Reasonable Guess For Screw Conveyor Diametre'
WRITE(*,*)'(STANDARD CONVEYOR SIZES:6,9,10,12,14,16,18,20,24)'
READ(*,*)F
IF(F.EQ.6.OR.F.EQ.9.OR.F.EQ.10.OR.F.EQ.12.OR.F.EQ.14)THEN
GOTO 105
ELSEIF(F.EQ.16.OR.F.EQ.18.OR.F.EQ.20.OR.F.EQ.24)THEN
GOTO 105
ELSE
WRITE(*,*)'INVALID ENTRY; CHOOSE FROM GIVEN STANDARD SCREW SIZES'
GOTO 110
ENDIF
C OPENING OF CHART A FILE TO READ VALUES OF STANDARD SCREW SIZES,
C SPEED (rpm) AT A UNIT CAPACITY, MAXIMUM RECOMMENDED SPEED AND
C ASSOCIATED TORQUE FOR EACH SCREW SIZE RESPECTIVELY
105 OPEN(UNIT = 2,FILE = 'SCHART_A.DAT',STATUS = 'OLD')
115 DO J = 1,9
READ(2,*) G(J), H(J), A(J), B(J)
IF (G(J).EQ.F)THEN
V = C / H(J)
WRITE(*,1)
WRITE(*,*)'Max. Rec. Capacity For Chosen Size = ',B(J),'m cu/s'
WRITE(*,*)'Max. Recommended Speed For Chosen Size = ',A(J),'rpm'
WRITE(*,1)
WRITE(*,*)'Estimated Speed For Screw Size = ', V,'rpm'
GOTO 117
ELSE
GOTO 115
ENDIF
117 IF (V.LE.A(J).AND.C.LE.B(J))THEN
WRITE(*,1)
WRITE(*,*)'Recommended Speed For Selected Screw Size = ',V,'rpm'
WRITE(*,8)'Design Capacity Is Within The Maximum Limit'
GOTO 120
ELSEIF (V.GT.A(J).OR.C.GT.B(J))THEN
WRITE(*,1)
WRITE(*,*)'Max. Recommended Speed Exceeded! DESIGN IS UNSAFE'
WRITE(*,*)'Max. Capacity For Screw Size Probably EXCEEDED'
WRITE(*,1)
WRITE(*,*)'RESTART DESIGN! RESELECT REASONABLE PARAMETRES'
CLOSE (UNIT = 2)
WRITE(*,1)
GOTO 50

END IF
END DO

```

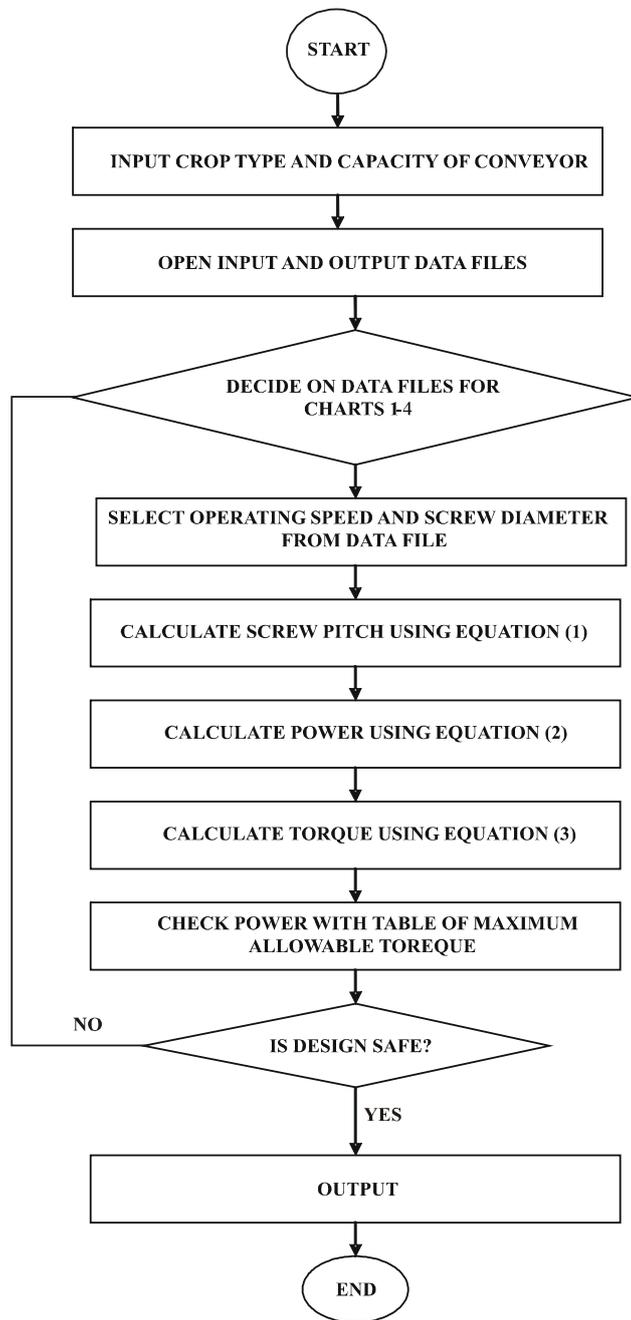


Fig. 1. Flowchart for the Computer Program