Consume Power Torque and Conveyor energy efficiency for a Horizontal Screw Conveyor with three different Screw Flight –A Comparison

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Research Article

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Abstract

Material handling cost plays crucial role in any manufacturing industries. A judicious selection of material handling system or equipment can only help to enhance productivity and thereby increasing profitability of an industry. Extensive studies require for establishing cost effective solution related to selection of right handling system. The objective of work is to find out running cost associated with screw type horizontal conveyor through experimental investigation of consume power and associated torque against three different types of screw flight(Continuous, Ribbon and Cut Flight) of same nominal diameter and pitch while keeping conveying distance as constant with same material at different screw speed. The experiment was conducted against two different trough heights for finding out mass flow rate. The consume power, torque and conveying energy efficiency calculated with three different screw flight and the results were compared for analysis. Hence on the basis of experimental results, conclusion was drawn. Present work confirming experimentally that the consume power at conveyor shaft and torque in case of ribbon flight was found to be 10 percent less than that of the continuous screw type of same nominal diameter, pitch and helix angle with same range of speed against single conveying material type in case of both the trough height(112 mm and 180 mm), which was in line with the statement made earlier[6]. In addition to that a trial has been made to establish a comparison in terms of consume power in between ribbon and cut flight against a constant trough height, which was not reported earlier. This comparative study may be helpful for taking decision in selecting material handling equipment type for specific application area. Now a day overall energy consumption becomes serious concern for different industries.

1. Introduction

A screw conveyor can be classified broadly into two categories; the U-shaped though type conveyor and the fully enclosed conveyor. The U-shape trough type casings are widely used in different industry. However, their operation being restricted to low angle of elevation, low speeds and low fill ratio. There is various type of flight depending on the applications. Short pitch, single flight continuous screw is recommended for inclined or vertical configurations while ribbon type flight is excellent for conveying sticky and viscous materials, eliminating collection and build up of material especially the space in between flight and shaft(both hollow or solid). On the other hand cut flight type screw design features is used for mixing and agitation of material in transit and very useful for moving material which have a tendency to pack. The summary of literature review as follows.

Nagel observed that the rotational velocity of a screw in rpm while raising water should not be more than $50/D^{2/3}$, where D is the diameter of the outer cylinder in meter. If the screw is rotated much faster, turbulence and sloshing prevent the cavities from being filled. Aston Fuch et al investigated a principle of reliable measurement of the mass flow of material through screw conveyor. He developed a novel, cost effective capacitive sensor which allows precise determination of the fill level and also speed of the screw. The mass flow rate through the conveyor pipe can be determined by means of one single sensor.

 pe conveyors” presented by Mr. Johannes Fottner, presented at the Engineering Meeting of Krupp Fordertechnik session, 28-29 February 2000. Characteristics of bulk material and their effects and influences on the conveying process in screw type conveyors, optimization of operational parameters, requirement of electrical power for plants with screw type conveyor were some important areas where Fottner, J worked.

Research has been carried out on “Design consideration and performance evaluation of screw conveyors” by Alan W. Roberts .This paper is concerned for screw conveyors with enclosed tubular casing. The throughput, torque and power were significantly influenced by the vortex motion of the bulk solid being conveyed.

Yu.Y and P.C. Arnold [1] has discussed about the power requirements of the screw feeder which is a principal parameter and related to the feeder load, properties of bulk solid, screw material and constructional features. A theoretical model of power and torque calculation was outlined for which experimental studies on screw feeder are reported. Two types of bulk material, three types of trough with different inner diameter and screws with different configurations are investigated. Indian standard specification **IS:5563:1985 [2]** has specified the dimensions of various parts and components of a screw conveyor with U-shaped trough, for various nominal sizes of the screw diameters, starting with 100mm diameter up to 1250 diameter. Indian standard specification **IS:12960:1990** [3] has recommended the method for calculation of power requirement of both horizontal and inclined screw conveyor. The text books by **Spivakovsky, A**. and **Dyachkov, V.** [4], **Ray, S.** [5] and **Alexandrov, M.P.** [6] provide valuable information and operational data for designing as well as operating screw conveyors. Amla Kurjak described the powder properties of conveying materials in a vertical screw conveyor. He reported that the clearance and free length of intake has significant impact on screw capacity. Zareifrouh,H.[8,9] did review on screw conveyor performance during handling process of agricultural grains and bulk materials. He further studied the performance characteristics of screw augur as a function of screw diameter, rotational speed and inclination. The effect of percentage trough loading on horizontal screw conveyor was investigated by Dixit, D.K.[10]. Santanu Chakarborty et al developed a CAD model of semi flexible screw conveyor and considered for adaptive design, which provides valuable information about different components of a screw conveyor. Ezzatollah et al[12] investigated the effect of screw speed, conveyor inclination with paddy grain verities on power requirement of a screw type conveyor. Present literature review reveals that few works has already been done on screw conveyor performance. The consume power, torque and conveying energy efficiency of different flight has not yet been reported experimentally, confirming the statement made by **Alexandrov, M.P.** [6]. In addition to that the trial has made to establish a comparison in between ribbon and cut flight type screw in terms of consume power and torque for 112 mm trough height, which was not reported earlier.

2. Mathematical Expression

The power requirement in kW may be calculated to the drive shaft of a horizontal screw conveyor [3].

$$P = \frac{QL\lambda}{367} + \frac{DL}{20} \quad \ldots\ldots(1)$$

where,

P express the consumed power in drive shaft of the horizontal screw conveyor in kW.

Q is the mass flow rate in t/h L is the effective conveying length of material movement in screw conveyor in m.

D as nominal diameter of screw in m .

λ is the progress resistance co efficient or friction factor, value considered as 4[6].

The torque on the screw shaft may be calculated as follows in N-m[8]

$$Mo = (60 \times 1000 \times P \times \eta)/(2 \times \pi \times n) \ldots\ldots (2)$$

where,

Mo is the torque in $N - m$

n rotational speed of screw in rpm.

η is the overall drive efficiency of the conveyor as 72.75% was considered .

Conveying energy efficiency (E) can be calculated as

$$E = \frac{Q}{1000 \times P \times t} \ldots\ldots (3)$$

t is the time interval, 1 hr as considered.

Mass flow rate can be measured performing experiment for 30 s experimental run of the horizontal screw conveyor with the help of stop watch and digital weighing machine considering each screw type at a time. Four set of reading is taken to minimize experimental error at single speed.

3. Experimental Methodology And Set Up

The experiment was conducted for three different screw having three various flight(Continuous, Ribbon and Cut flight) of identical nominal diameter, pitch and helix angle with easy replacement facility, so that each of screw type integral with tubular shaft installed within the same U-trough of interchangeable trough covers of different trough height (112 mm and 180 mm respectively) during experiment. The reading was taken for single flight type while using 112 mm trough cover at four level of screw speed (12, 15, 21 and 26 respectively) as there was a provision for speed changing facility through variable frequency drive[7] installed with the conveyor itself. Then trough cover was changed with the same set up and reading was taken further for 180 mm trough cover at same four level of screw speed. Then screw type was replaced with another flight and the procedure was repeated for remaining flight type. During experiment for 30s run time the mass flow rate (Q) was measured with the help of stop watch and digital weighing machine of 50 kg with 1 gm resolution. The experimental methodology was expressed with the help of three no. of tables as follows.

Table 1
Nomenclature for experiment and description

Notation used	Description	Notes
C	Continuous flight	Identical nominal diameter, pitch and helix angle was used for experiment.
R	Ribbon flight	
CF	Cut flight	
Th112	Trough height 112 mm	Using two different trough cover
Th180	Trough height 180 mm	

Table 2
Possible cases considered for experimental result.

Screw Conveyor Parameters	Trough Cover					
	Th112			Th180		
	C	R	CF	C	R	CF
Case Considered	Case-1	Case-4	Case-5	Case-2	Case-3	Case-6

The experiment was conducted as per following sequence to minimize set up with installation effort and time.

Table 3
Cases along with descriptions and notes

Case Considered	Descriptions	Notes
Case-1	C with Th112	Four level of screw speed(12, 15, 21 and 26 respectively) considered in each case
Case-2	C with Th180	
Case-3	R with Th180	
Case-4	R with Th112	
Case-5	CF with Th112	
Case-6	CF with Th180	

The output responses like consume power, associated torque and conveying energy efficiency was calculated based equation no 1, 2 and 3 respectively. Experimental result was compared and analyzed further. Conclusion was drowned based on experimental result for three different designs of flight. Different input parameters as well as output response were tabulated as follows.

Table 4
Input parameters and out put response

Input Parameters		Output Response
Fixed	**Variable**	
Conveying material type.(Dry coarse Sand)[14-18]	Trough height (112 mm and 180 mm respectively)	Consumed Power on drive shaft(P)
Bulk density of conveying material(γ) (value 1.572 t/m^3)[14-18]	Types of screw flight (C,R and R)	Torque(M_o)[8]
Length of transportation or conveying length(L)(1.48 m was considered)	Screw speeds(n) (12, 15, 21, 26 rpm Respectively)	Conveying energy efficiency(E)
Nominal Screw diameter (D)(0.2m was considered)		
Pitch of the Screw(S)(0.16 m)		

Table 5
Specification of Screw conveyor for experiment

Screw Diameter[1-6],[14-18]	**200 ±1mm**
Screw Types[1-6],[8-10]	Continuous, Ribbon and Cut flight
Screw Length[1-6],[8-12],[14-18]	2000mm
Screw Pitch	160mm
Screw Fixing Arrangement	Flanged at both ends [3-5].
Screw shaft[2,5]	48.3·3.5 mm pipe, M.S
Thickness of Screw/Material	4mm/M.S
Screw Supporting Bearing[3-6]	Spherical roller bearings on both ends
Trough Shape[2-6]	U
Trough Width[2,5]	220 mm
Trough Height form Center of Screw	Experiment was conducted at two different trough height at 112 mm and180 mm respectively.
Feeding Hopper	Trapezoidal section, shift-able over the trough.
Feeding Arrangement	Manual ensuring flood feeding condition
Maximum effective length of Screw (Hopper center line to edge of discharge spout)	1480 mm and adjustable up to maximum of 1520 mm.
Drive Motor	220 Volt, 2.2 kW, 3 Phase, 4 Pole
Gear Box	Worm Reducer, 25:1 ratio, Size CTS inch, Fan Cooled, Under driven, Right Hand handing, Approved make.
Speed controller	Frequency control drive. Speed ratio is 10:1 with frequency/ rpm indicator [7].

Screw Diameter[1-6],[14-18]	200 ±1mm
Structural Details	Fabricated structure at drive and non-drive end connected with necessary stretchers [4-6].

4. Result Analysis And Discussion

The experiment was designed to perform with two distinct levels of trough height separately using two different trough cover(Th112 and Th180) along with three screw flight type(C, R and CF) having same nominal diameter, pitch and helix angle and keeping the conveying length as constant with single conveying material type(dry coarse sand) and against four levels of screw speed (12, 15, 21 and 26 rpm respectively). Following observations was found from experimental result cosidering six different cases (Case-1 to Case-6) which was further enumarated with the help of six graphical representations.

4.1 Variation of consumed power(P) with respect to screw speed(n)

The consumed power(P) in Case-4 lies in between Case-1 and Case-5 and Case-3 lies in between Case-2 and Case-6. More preciously, the value of consume power(P) for Case-4 was very similar to the mean of Case-1 and Case-5. The consume power(P) at conveyor shaft for Case-4 was near about 10 percent less than that of Case-1 and for Case-3 was near about 10 percent less than that of Case-2 against constant conveying distance for single conveying material, which was inline with statement [10].While increasing trough height from 112 mm to 180 mm consumed power(P) for Case-5 has a tendency to shift more towards Case-4, which was not reported earlier.

4.2 Variation of torque(M_0) with respect to screw speed(n)

Torque Characteristics(M_0) Case-4 lies in between Case-1 and Case-5 and Case-3 lies in between Case-2 and Case-6 and more precisely the value of the torque for Case-4 was very similar to the mean of Case-1 and Case-5 for Th112. While increasing trough height from 112 mm to 180 mm, torque characteritics for Case-5 has a tendency to shift more towards Case-4.

4.3 Variation of conveying energy efficiency(E) with respect to screw speed(n)

Conveying energy efficiency(E) found to be maximum value Case-2 and minimum against Case-5 for both the trough cover(Th112 and Th180). However it’s value was slightly increasing trends with respect to screw speed for all flight types at both the trough cover. It has got more impact on screw speed rather
s of E with respect to flight type at various srew speed. The

variation of E with respect to flight type was observed in case of Th112. However, the variation of E was not so distinct Th180.

5. Conclusion

Among three flight type, continuous flight was found to be expensive in terms of consumed power and associated torque characteristics in case of both the trough covers(Th112 as well as Th180) for constant conveying distance of 1480 mm with same conveying bulk material as dry coarse sand. Continuous type screw has got maximum power consumption while operating at 26 rpm against Th180 with same conveying bulk material. The consumed power at conveyor shaft in case of ribbon flight was near about 10 percent less than that of continuous screw type of same nominal diameter, pitch and helix angle with same speed range against fixed conveying distance for single conveying material in case of both Th112 and Th180, which was confirmed experimentally. For Th112 the consume power(P) and torque(M_0) with CF was(8 to 10) percent less than that of ribbon type flight of same nominal diameter, pitch and helix angle. Which was not been published earlier. However, for Th180 the consumed power for ribbon and cut flight screw showed almost similar result, which was due to the fact that higher trough height(Th180 is equal to 1.6 times of Th112) was responsible for the vortex motion together with high degree of fill without the use of intermediate bearing hanger in a flood feeding condition with a short conveying distance(less than 2 m).Thus the throughput, torque and consumed power for ribbon and cut flight type screw was significantly influenced by vortex motion of bulk material being conveyed. Trough height probably has got significant impact on consumed power as well as torque in case of short (less than 2 m)horizontal screw conveyor with flood feeding condition. At Th180 mm trough height(1.6 time than another trough cover) found to be expensive in terms of consumed power and torque rather than Th112 in case of all three flight type. The effect of screw speed on conveying energy efficiency was observed and found slightly increasing trends with respect speed. It's value was found to be within a range of 0.048 to 0.058 t/w-h at experimental range against both the trough cover. Throgh height has got little impact on conveying energy efficiency rather than speed and flight type.

6. Future Scope

A similar experiment may be conducted for higher speed range and the effect needs to be studied. Present experiment was conducted with a bulk solid (dry sand), the experiment may be conducted with free flowing material. The dependence of power factor need to be investigated further.

Declarations

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Editorial Comment

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b. Conflicts of interest/Competing interests (Authors are required to disclose financial or non-financial interests that are directly or indirectly related to the work submitted for publication. Interests within the last 3 years of beginning the work (conducting the research and preparing the work for submission) should be reported. Interests outside the 3-year time frame must be disclosed if they could reasonably be perceived as influencing the submitted work.)

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Editorial Comment

c. Availability of data and material (data transparency)

Author's Reply: On reasonable requests by reviewers for materials, data, and associated protocols must be fulfilled. Data to present manuscript can be found online from reference section of the manuscript (Refer serial no. 14, 15, 16, 17 and 18 of Reference)

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d. Code availability (software application or custom code)

Author's Reply: All BIS related to present manuscript are available online. Work is experimental in nature; hence software application or custom code is Not applicable for this manuscript.

Editorial Comment

e. Ethics approval (include appropriate approvals or waivers)

Author's Reply: All previously published articles were well cited in the present manuscript in the reference section and all cases First author is the present author.

Editorial Comment

f. Consent to participate (include appropriate statements)

Author’s Reply: 'Not applicable'.

Editorial Comment

g. Consent for publication (include appropriate statements) If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format.

Author’s Reply: Figure-1, Typical experimental set up and Table-5, Specification of Screw conveyor for experiment was already published in the Book chapter under LNME Springer Nature with present Author, which is cited in present manuscript as reference.

Editorial Comment

h. Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory)

Author’s Reply: Manuscript submitted as Single author.

Editorial Comment

If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

Author’s Reply: Noted. and incorporated.

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Figures

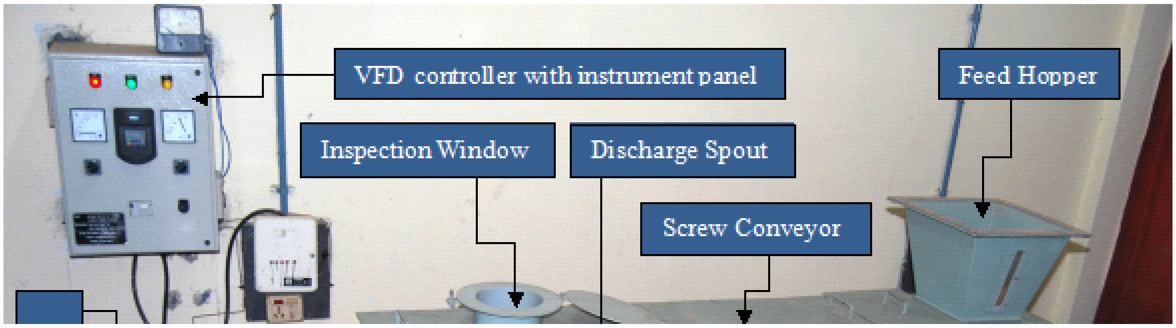

Figure 1

Typical experimental set up

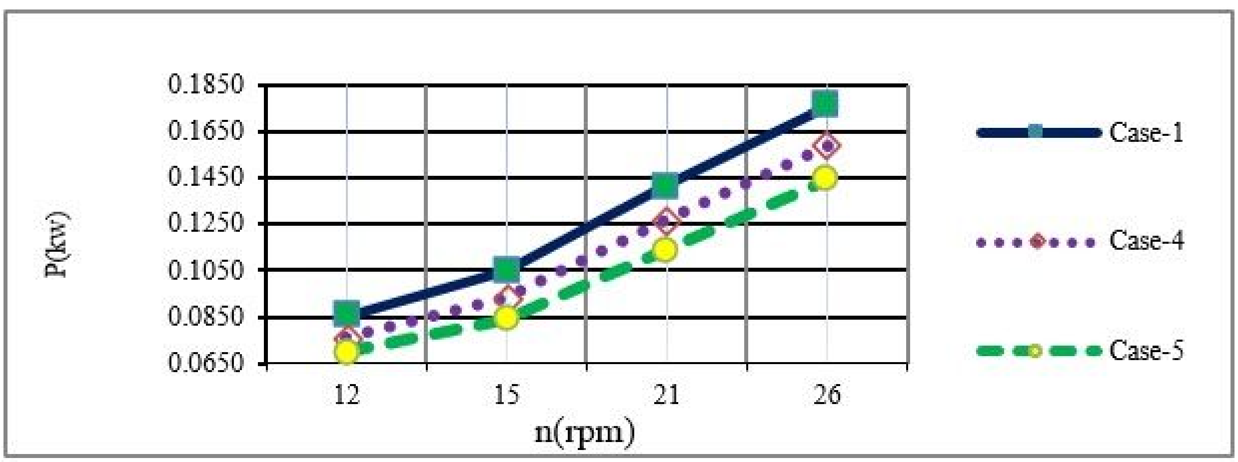

Figure 2

Variation of P with respect to n for Case-1,Case-4 and Case-5

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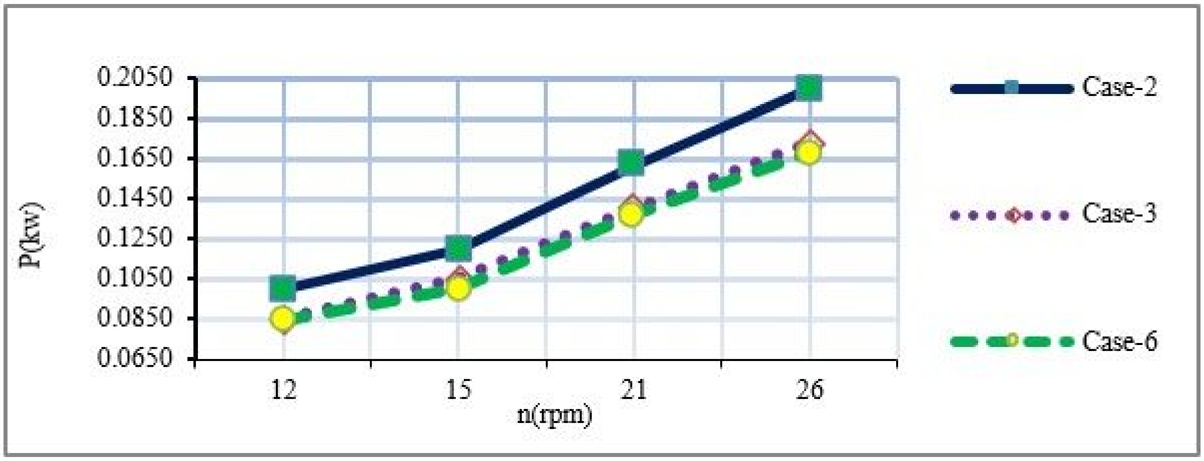

Figure 3

Variation of P with respect to n for Cae-2,Cae-3 and Case-6

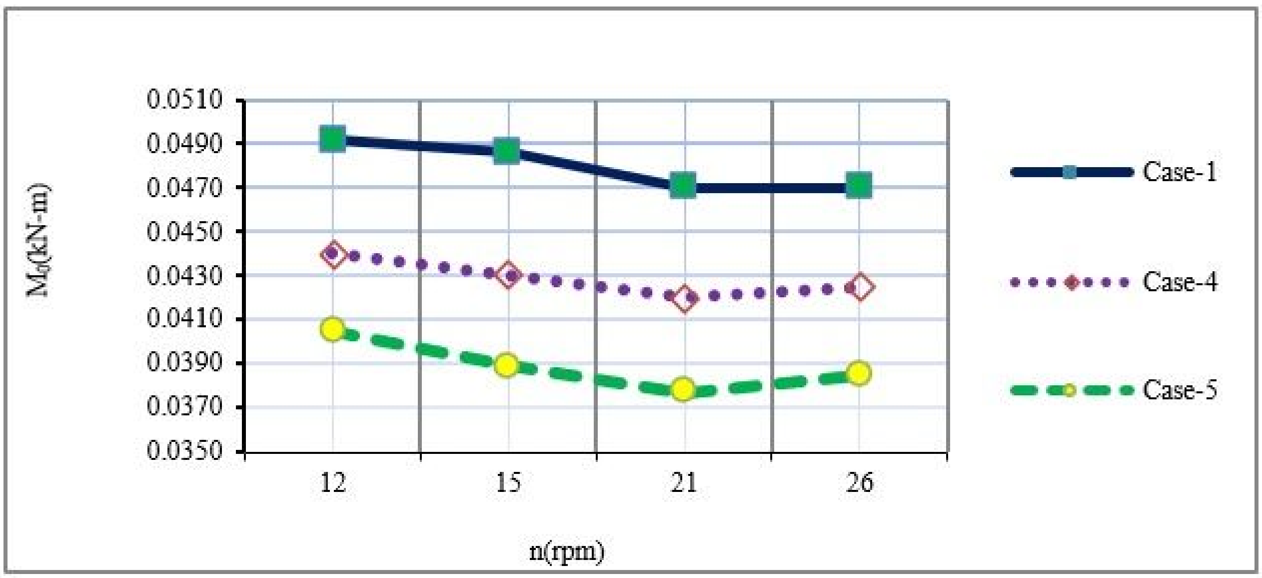

Figure 4

Variation of M0 with respect to n for Case-1, Case-4 and Case-5

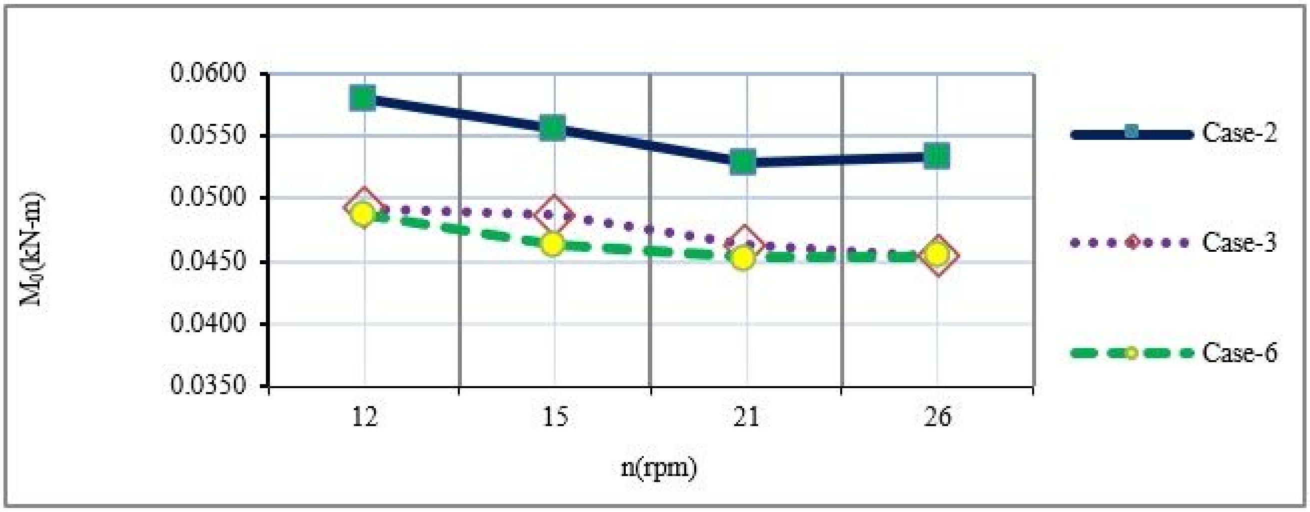

Figure 5

variation of M0 with respect to n for Case-2, Case-3 and Case-6

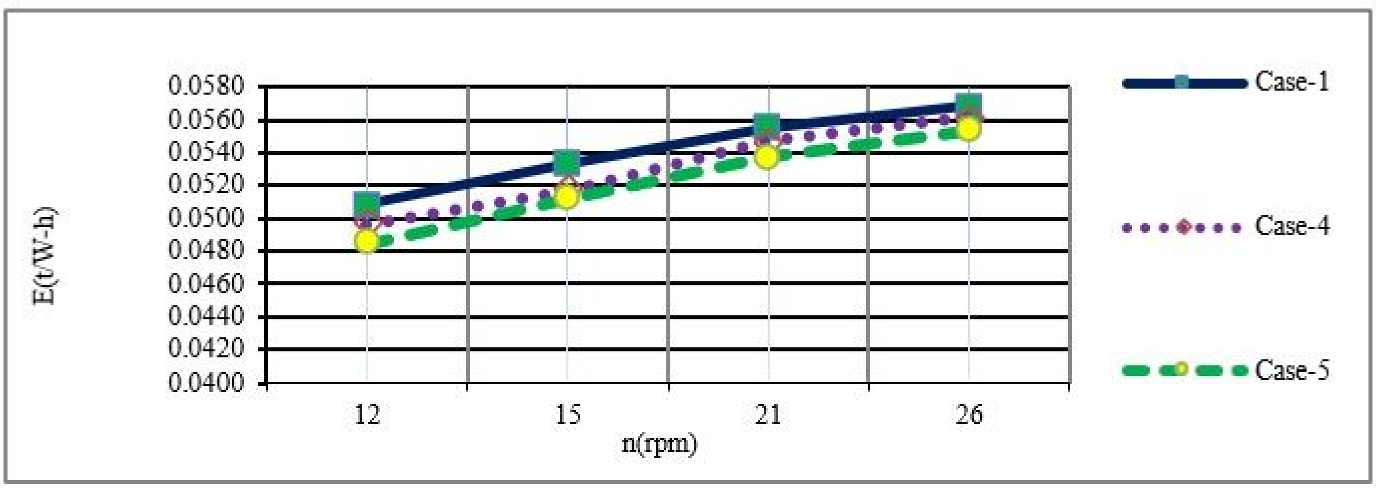

Figure 6

Variation of E with respect to n for Case-1, Case-4 and Case-5

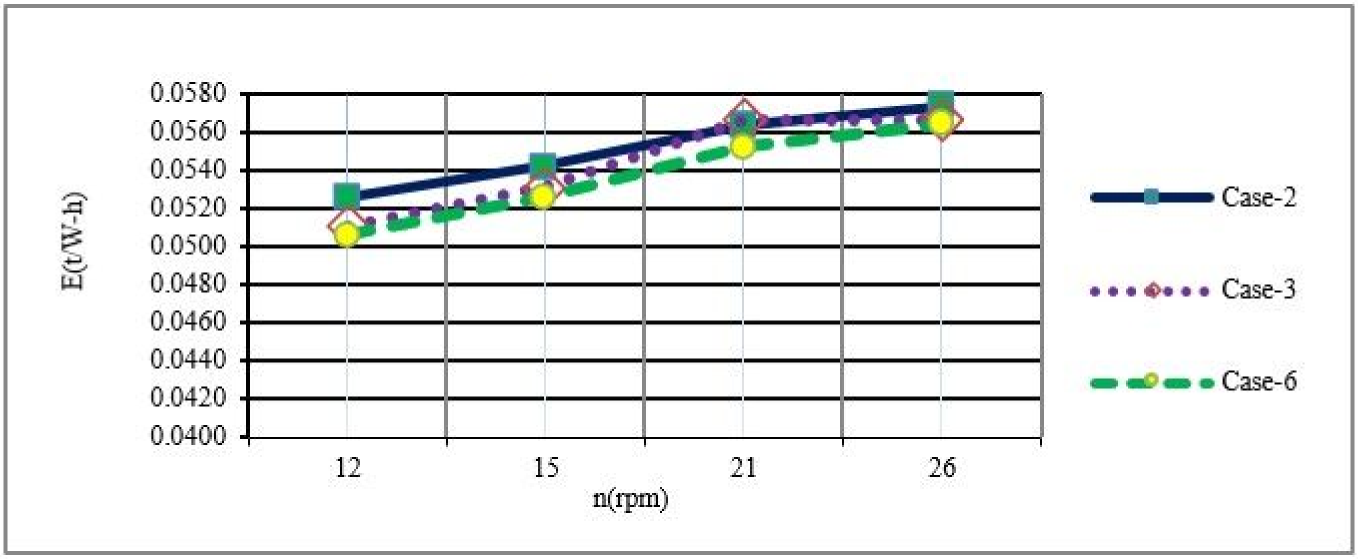

Figure 7

Variation of E with respect to n for Case-2, Case-3 and Case-6