BELT WEAR AND ENERGY CONSUMPTION OF CONVEYOR BELT ACCESSORIES

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1. INTRODUCTION

In the handling of bulk solids on conveyor belts, the prerequisite for reducing carry back and the consequential spillage is a key operating worry due to the cost of cleanup and safety. The cost of belting is a core operating cost and any attempt to improve the service of the belt has a noteworthy impact on profitability[2]. This study considers conveyor belt accessories, the wear on the belt as well as the energy consumption of accessories.

The paper investigates the trade-off in terms of belt cover life, when deciding to use an engineered conveyor belt system[4]. Also, the flow of bulk material through the transfer point and the loading on the receiving conveyor is an opportunity for energy saving. The number, type and adjustment of belt cleaners have a significant effect on energy consumption as well [3].

2. BELT CLEANERS AND THEIR INTERACTION WITH CONVEYOR BELT LIFE

a. Test equipment used

Rubber, polyurethane and tungsten carbide blade materials were tested on a specially designed test rig and compared to a standardised abrasion test method [4].

The standardised abrasion tester used was a Zwick 6102 Abrasion tester

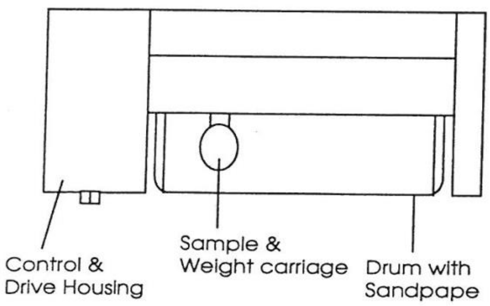

Figure 1. Zwick tester schematic (overhead view) [4]

The Top Cover Abrasion Tester, (TCAB), that was specially designed for this belt wear project is of similar operating technique and design as the Zwick machine. The primary difference is the sandpaper abrader that was replaced by a seamless tube of Goodyear conveyor belt top cover material, which is approximately 12mm thick [4].

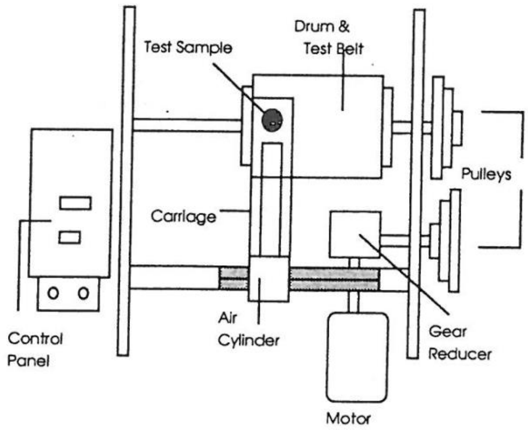

Figure 2. TCAB tester schematic (overhead view) [4]

TEST MATERIAL	HARDNESS (Shore A)	DENSITY (g/cm^{3})	DIN# (Zwick / 53 516)
A-9 Polyurethane	90	1.27	50.8
Rubber	65	1.24	130.4
Tungsten Carbide	NA	14.81	0.3
Test Belt	70	1.24	205.7

Table 1. Test samples [4]

b. **Test method**

Most tests were run using polyurethane samples. The results of these determined the design of the tests on other materials. A total of twelve tests were run at different pressures. The standard test consisted of a run time of 20 hours. Prior to the test, both the belt and sample were stabilized for temperature and humidity and weighed. This was also repeated at the end. Every hour the total mass loss from both belt and sample was collected and weighed [4].

c. **Test results**

It was observed that wear occurred on only a portion of the blade sample, thus having an effect on the actual contact pressure [4].

Measurements of the samples provided the tester with the impression that the actual contact pressure was double the design pressure. The wear of the belt was greater than the wear of the sample in all cases on an absolute mass loss basis. An estimate of belt life and blade life could be developed and extrapolated for various thicknesses of top cover and belt length, as well as blade materials [4].

The next test was to consider how the belt cleaner will wear a belt in comparison to having no belt cleaner at all?

A test was run with the belt half submerged in dry sand. The life of the belt in the sand was less than that predicted by blade wear. The average belt life of all three calculated urethane blade material was 19.5 years. The calculated belt life, if allowed to run in sand, was 8.5 years, less than half as long[4]. (Swinderman & Lindstrom 1995).

d. **Conclusion**

The highest wear rate for both blade and belt occurs when there is no material on the belt. The wear mechanism depends on the amount of heat generated in the blade and top cover [4].

This result supports the field observation that the wear process is approximated to be a linear relationship, depending on the pressure used and the amount of mass available for wear in both the belt and the blade [4].

The results also lend credence to the use of the Zwick tester as an indicator of elastomeric blade life, which was also observed in a field test [4].

3. POWER CONSUMPTION OF CONVEYOR BELT ACCESSORIES

Conveyor design technology has evolved over the past century from empirical and often proprietary estimates of the accumulated effect of the loss sources. In the 1960's one of these methods was published by CEMA in their first Belt Conveyors for Bulk Materials design guide [5].

Researchers continue their pursuit of understanding the energy loss and power requirements due to various components and the system operating conditions, especially that of belt tension. The works of Behrens and Spaans stand out for the latter [5].

Behrens' tests using a loaded stationary conveyor and a moving set of idlers showed quantitatively the effect of the operating tension on the energy loss. He correlated reduced loss to decreasing belt sag between idlers due to increasing tension as well as idler spacing. Hager and Hintz referenced these results in a compilation of seven loss sources, including the almost obvious and often dominant role of conveyor inclination. For the horizontal conveyor case, their pie chart shows 61% of the energy loss to be due to idler roll indentation in the conveyor system.

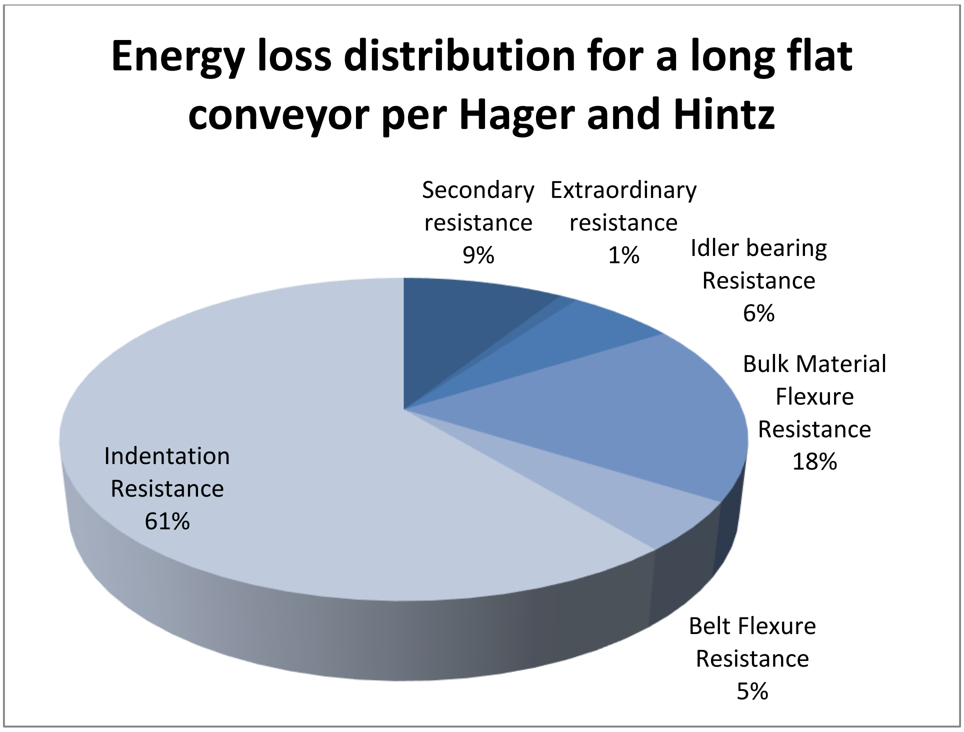

Figure 3. Energy loss ditribution for a long, flat coveyor

Hager and Hintz

This adds to what is stated in FOUNDATIONS™ fourth edition, chapter 14, that adding belt products, in this case secondary scrapers, will impact the power draw on a conveyor belt. A test conveyor was used to take measurements of the power draw on the conveyor drive motor. The results were then compared to the calculated values.

a. Test method & equipment

In order to conduct the experiment, the following equipment was used:

- Test conveyor belt rig with the following relevant specifications:
  - 1050mm Belt
  - 30kW 4pole 3-phase motor
  - 18m Head-to-Tail pulley
  - 500mm diameter Head pulley, giving us a measured belt speed of 4.3m/s
- 3-phase 4-wire electric meter (Landis & Gyr E650)
- Various belt products

The electric meter was connected to the control panel of the test conveyor at the main switch in order to get the total power draw on the system. To establish a good baseline, the testing conveyor was run on different days at different times. To get the baseline, the testing conveyor was dry, without any material and no conveyor products touching the belt.

Two different scrapers were tested to double check the results. The electric metering equipment data capturing frequency was 1 minute, so the tests were run for 30 minutes to get comprehensive data. The results of each 30 minute run were downloaded to a laptop in EXCEL format and reviewed.

An issue encountered with the first test with a scraper, was that the results were very high and not what was expected. This was due to the fact that the belt was never run dry before for such an extended length of time, so the top cover of the conveyor belt was still very rough and had first to be scraped smooth. After we saw this, the testing conveyor was reset and the test was run again.

The belt products tested and considered to be most relevant to the purpose of this paper was:

- Secondary Belt Cleaner 1
- Secondary Belt Cleaner 2
- Diagonal Return Plough
- V-Plough
- Skirting

These products were tested on their own as well as various combinations to simulate real world installed products. The secondary scrapers were installed in a double secondary scraper configuration, with the Secondary belt cleaner 2 being in front i.e. nearest to the Head pulley.

Once all the products were tested during the second run, the top and bottom of the belt was sprayed with a garden hose in order to establish the effect normal water would have on the scrapers.

Some tests were run multiple times and an average was taken.

The tests we conducted were:

- Baseline run
- Secondary Belt Cleaner 1 (SBC1)
- Secondary Belt Cleaner 1 (SBC1)under tensioned
- Secondary Belt Cleaner 1 (SBC1)over tensioned
- Secondary belt cleaner 2 (SBC2)
- Secondary belt cleaner 2 (SBC2)over tensioned
- Secondary Belt Cleaner 1 (SBC1) & Secondary belt cleaner 2 (SBC2) in double configuration
- Secondary Belt Cleaner 1 (SBC1) at head pulley
- Secondary Belt Cleaner 1, Secondary belt cleaner 2, Diagonal Return Plough & V-Plough (various products)
- Secondary Belt Cleaner 1, Secondary belt cleaner 2, Diagonal Return Plough & V-Plough with wet belt (various products)

	Clean dry Belt Run 1	Clean dry Belt Run 2	SBC 2 Normal run 1	SBC 2 Normal run 2	SBC 2 Over tensioned	SBC1 Normal run 1	SBC1 Over Tension	SBC1 at Head Pulley	Various Products Dry Belt	Various Products Wet Belt
Amp (A)	28.1452	28.18	29.86	28.79	29.52	28.15	30.09	29.71	31	28.83
Volts (V)	228.4317	232.87	233.08	230.74	229.21	229.15	227.19	231.71	231.04	229.85
Power (Kw)	6.429	6.562	6.960	6.643	6.766	6.451	6.836	6.884	7.162	6.627
Power draw	0.0388	0.0296	0.0464	0.0435	0.052	0.0409	0.0582	0.0471	0.0597	0.0456

b. Test results

Table 2. Measured average power consumption

After each test, the results were tabulated for easier view. None of these values were calculated. They were all directly downloaded from the electric metering device.The following graphs consider the power drawn from the motor for each test:

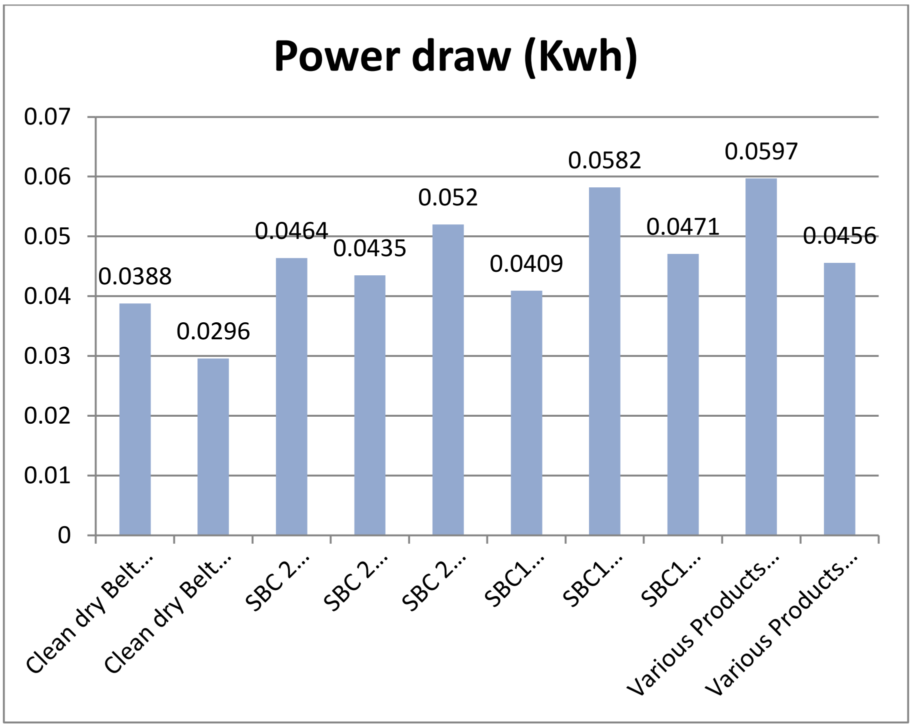

Figure 4. Power draw (kWh)

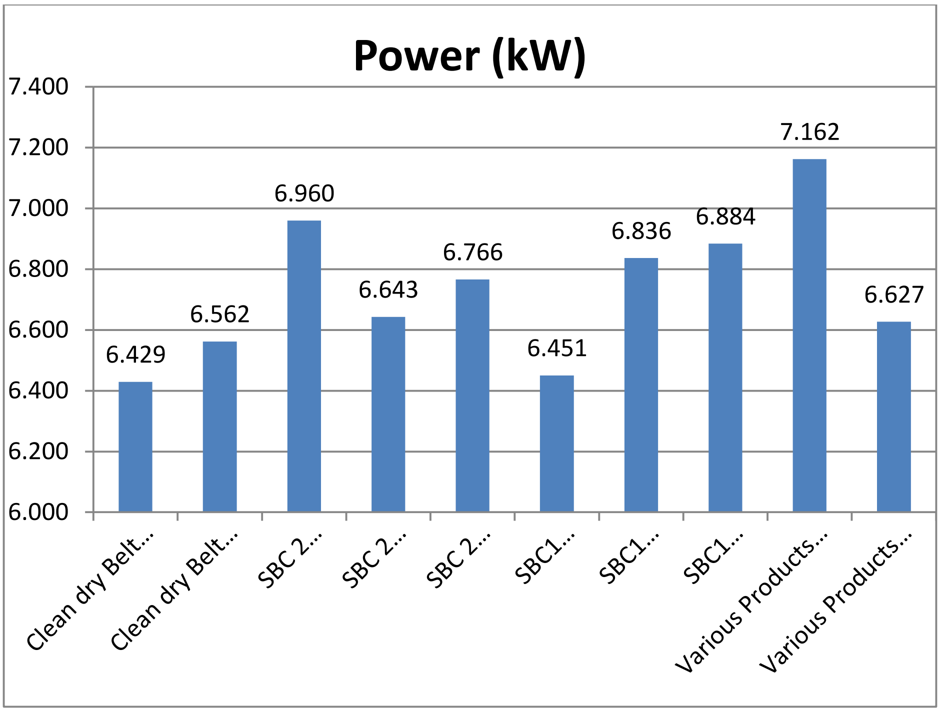

Figure 5. Power (kW)

c. Discussion

Should one then consider the formula as provided in FOUNDATIONS™?

Known values and data of test rig:

- Belt width[2] 1050mm
- Belt speed[2] 4.3m/s
- Friction Coefficient of tungsten[1] 0.62

FORMULA IS ONLY APPLICABLE TO SECONDARY BELT CLEANERS

Tension added to belt due to cleaner:

$$\Delta T_{BC} = I_{BC} \times \mu_{BC} \times F_{BC}$$

Where:

$\Delta T_{BC} \rightarrow Tension\ added$ (N)
$\mu_{BC} \rightarrow Friction\ Coefficient^1$
$F_{BC} \rightarrow Normal\ Force\ between\ belt\ \&\ cleaner\ per\ length\ of\ cleaner$ (N/mm)
$I_{BC} \rightarrow Length\ of\ cleaner\ blade$ (mm]

Thus, substituting all values

$$\Delta T_{BC} = (1050) \cdot (0.62) \cdot (0.088) = 57.288\ N \qquad 2$$

From this can be seen that each secondary scraper, edged with a tungsten tip, adds 57.288N of tension to the test belt. Following this, one can calculate the extra power needed by the motor to overcome the added tension.

(See notes 1 and 2)

Calculating Power consumption added to the belt drive.

$$P = \Delta T_{BC} \times V \times k$$

Where

$P \rightarrow Power\ consumption\ added$	(kW)
$\Delta T_{BC} \rightarrow Tension\ added$	(N)
$V \rightarrow Belt\ speed$	(m/s)
$k \rightarrow Conversion\ factor$	

Thus, substituting all values

$$P = (57.288) \cdot (4.3) \cdot \left(\frac{1}{1000}\right) = 0.2463\ kW \qquad 3$$

Here it can be seen that according to the formulae used, each secondary tungsten-tipped scraper should add 0.2463 kW of power consumption to the test conveyor.

Let us consider secondary belt cleaner 1 and secondary belt cleaner 2 and compare to the belt when run clean (no scrapers) using the obtained values in Table2.

Belt cleaner 1:

$$average\ power\ draw = \frac{6.884 + 6.836 + 6.451}{3}$$

$$= 6.7237kW$$

Belt cleaner 2:

$$average\ power\ draw = \frac{6.766 + 6.643 + 6.96}{3}$$

$$= 6.7897kW$$

Clean belt:

$$average\ power\ draw = \frac{6.562 + 6.429}{2}$$

$$= 6.4955kW$$

Now to calculate the added power draw on the belt caused by the belt cleaners, we subtract and compare to the theoretical values obtained:

$$added\ power_{scraper\ 1} = 6.7237 - 6.4955$$

$$= 0.2282kW$$

$$added\ power_{scraper\ 2} = 6.7897 - 6.4955$$
$$= 0.2942kW$$

If we now consider the tests run where only 4 products were installed on the test conveyor:

$$average\ power\ draw = \frac{(7.162 + 6.627)}{2}$$
$$= 6.8945kW$$

$$added\ power_{various} = 6.8945 - 6.4955$$
$$= 0.399kW$$

d. Conclusion

Considering both the calculated and actual results, one can see that the actual results are indeed close to the theoretical values. The formulae found in FOUNDATIONS™ are, therefore, a feasible way to calculate the added tension on a belt due to the addition of various belt accessories, especially belt cleaners.

Should one take into account how small the area of the scraper that is in contact with the belt, there is a relatively big draw in power that needs to be overcome by the motor that gets overlooked quite too often by the conveyor designers. The amount of accessories that can be put on a belt, resulting in added tension, and therefore, added power needed to drive the belt, can quickly add up. In the test with various products, we can see a power increase of 6%. If we consider the amount of products that is installed on the common conveyor belt, it is clear that this can have a snowball effect on the power draw of any conveyor. It is, therefore, critical that all the belt accessories be considered when designing and maintaining a conveyor belt in order to ensure the correct selection of the power pack.

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4. Swinderman Todd, R. & Lindstrom D., 1995, *Belt Cleaners and Belt Top cover wear,* 5th International Conference on Bulk Materials Storage, Handling and Transportation, 9-12 July
5. Reicks, A.V., 2012, *Conveyor Models as Quantitative Platforms for Belt Conveyor Energy Options,* International Conference on Bulk Materials Storage, Handling and Transportation, Bulk Solids Europe
6.

NOTES

1. Friction coefficient from CEMA, sixth edition, Table 11.73, Coefficients of friction for typical accessory materials, p341
2. Normal force of scraper on belt from FOUNDATIONS™, fourth edition, Equation 14.1, Calculating tension added, p234

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