Alternative Power Source for Dental Hygiene Device

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Abstract

The NAU department of Dental Hygiene provides humanitarian aid to some parts of the world. Many of these places have limited access to electricity. This creates a problem for the Department of Dental Hygiene since many of their tools require electric power. Therefore, they need a power source which can provide continual electric power for their devices. Meanwhile, this power source has to be portable in both size and weight. The task of our team was to design a power source that would allow the Department of Dental Hygiene to operate their Wig-L-Bug mixer tool off the grid for a full day. This design consisted of a lithium polymer battery, an inverter, and a charger. At the end of the last semester in 2012, a portable power source was designed and built. With this power source, the Department of Dental Hygiene successfully provided the humanitarian aid to children in Mainpat in December, and reported that they were satisfied with the performance of this power source. In this semester, the team came up another design idea, a mechanical Wig-L-Bug, which requires only manual power to operate. The team succeeded in building and testing the mechanical Wig-L-Bug. The main advantage of the mechanical Wig-L-Bug is that no charging process is required and it is much more portable. The mechanical Wig-L-Bug depends on no electricity so it can work properly in area where there is no access to electricity.

Table of Contents

1. Introduction

1.1. Problem Statement

The NAU Department of Dental Hygiene provides humanitarian services in some remote areas of the world. Sometimes, these areas have limited access to electricity. A dental device, called a "Wig-L-Bug", is used to mix cavity filling material. The Wig-L-Bug requires electricity to run. Since there is no electricity supply available, the team needed to design an alternative power source for the dental device.

1.2. Objectives

The Design team was asked to build a power supply. It should be capable of powering the Wig-L-Bug for an entire work day. The power supply will be small and light, so that it can be carried conveniently. It also needs to be durable enough for rough transport so the power source requires no maintenance for the duration of the trip to Mainpat. Besides, the manufacturing cost should be as low as possible.

1.3. Constraints

In the process of designing and building power source, the design needs to meet all following constraints. Firstly, the design must power dental device continuously for 10 hours. In order to make it portable, this power source cannot weigh more than 26lb and can fit in a 22in $\times$18in$\times$10in container. Moreover, it should take no more than eight hours to charge power source from 0 to 100% if a battery is used in the power source design.

2. Design Concepts

The team came up with two designs. The first one was a battery design, which was proven to work successfully during the 2012 semester. The second was a Mechanical Wig-L-Bug. The team completed the Mechanical Wig-L-Bug design during the 2013 semester. The mechanical Wig-L-Bug requires no electricity. It works with manual power input using a hand crank. A gearbox is used to increase the angular velocity from 75 RPM to 5000 RPM. The mechanical Wig-L-Bug is portable in both weight and size. The biggest advantage of the mechanical Wig-L-Bug design is that it works perfectly even there is no access to electricity.

3. Design Details

3.1.Battery Design

In the battery design, the team mainly used the battery as the power supply for the project. Besides, the team used an inverter to convert the power of battery so that it could be used by the Wig-L-Bug.

3.1.1. Battery

For the battery, the team needed a battery and the regulated voltage had to be 12 V. The battery is shown in Figure 1. The capacity of this battery had to be 240W·h, and the weight of this battery is 4lb. The specifications of this battery are shown in Table 1.

Table 1.Specifications of Battery

Capacity	240 $\mathbf{W \cdot h}$
Nominal Voltage	16.8 V
Regulated Voltage	12 V
Maximum Discharge Rate	10 A
Dimensions	8in ×5in×3in
Weight	4 lb

Figure 1.Battery

3.1.2. Inverter

An inverter is used to convert the battery power so can be used by the Wig-L-Bug. Figure 2 shows the inverter which the team used in the battery design, and some specifications of this inverter are contained in Table 2.

Table 2.Specifications of Inverter

Specification	Pure sine wave inverter
Input Voltage	12 V DC
Output Waveform	Pure sine wave
Output Voltage	120 V AC at $60H_z$
Power Output	180 W
Maximum Efficiency	90%
THD	<3%
Size	6in ×3in×2in
Weight	1 lb

Figure 2.Inverter

3.1.3. Charger

A charger is used to charge the battery. In India the standard voltage is 220V. Therefore, the charger must work with the voltage.

Table 3.Specifications of Charger

Input Voltage	100 – 240 V
Output Voltage	16.8 V
Fully Charge Time	9 h
Dimension	6in ×3in ×2in
Weight	1 lb

3.1.4. Cost Analysis

Since the cost is one of the most important criteria in the project, the team got every item how much is cost. Table 4 is a cost analysis of battery design. The team used one battery which cost $322.95, one inverter which cost $85 and one charger which cost $36.95. Therefore the total cost of this design is $444.90.

Table 4.Cost Details of Battery Design

Components	Quantity	Price	Subtotal
Battery	1	$322.95	$322.95
Inverter	1	$85.00	$85.00
Charger	1	$36.95	$36.95
Total			$444.90

3.2.Mechanical Wig-L-Bug

3.2.1. Gearbox Calculation

The gearbox was designed to reach a gear ratio of 1:72 in three steps. Using a safety factor of 3, the gear loads and sizes were calculated. Table 1 presents all the calculations. The modified Lewis form factor equation with the Barth Velocity factor was used to calculate the required material and minimum face-width for each gear. Cost and availability was also considered for the gear selection. The team decided to go with high carbon steel, 20 pitch, 20 ° and pressure angle spur gears with plain bores and .5 inch face width. Plastic gears were considered, but rejected due to not meeting strength requirements.

Table 5 Gear calculations

	Rotation Speed (RPM)	z	Torque (N·m)	Tooth Load (N)	Pitch Line Velocity (FPM)
P1	72	72	19.81	433	69
G1	217	24	6.60	433	69
P2	217	72	6.60	144	208
G2	1042	15	1.38	144	208
P3	1042	72	1.38	30	997
G3	5000	15	0.29	30	997

3.2.2. Gear Shaft

The gears welded to shafts made of low carbon steel. The gear shafts have a minimum safety factor of 4. They have been machined to a rough finish.

3.2.3. Bearings

The gear shafts ride on double sealed ball bearings intended for skateboarding applications. The bearings have a self-contained lubricant, and will last for the life of the mechanical Wig-L-Bug.

3.2.4. Housing

The housing for the gearbox was constructed from .25” polycarbonate sheet. Polycarbonate was chosen for its strength, cost, and ease of machining. The sides were glued together using a synthetic rubber polymer adhesive. The case was completely sealed in order to resist vibration in operation.

3.2.5. Crank Handle

On the input shaft, the team attached a rank handle. The structure of the crank handle is presented in Figure 3.

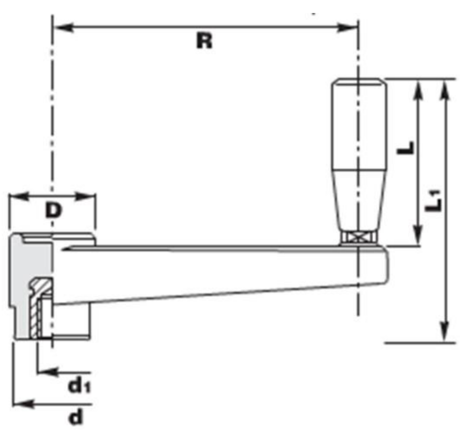

Figure 3: Structure of crank handle

The material of the crank handle is aluminum since it is light and strong. The arm length of the handle is 8 inches because it feels comfortable for a person to crank at 75 RPM. The team pinned the end of the shaft to the handle. The specification of the handle is shown in Table 6.

Table 6: Specifications of Crank Handle

Material	Aluminum
Bore Diameter, d (in)	1.58
Arm Length, R (in)	7.29
Hub Diameter, D (in)	1.85
Handle Length, L (in)	3.39
Overall Height, L1 (in)	5.28
Bore Diameter, d1 (in)	0.38

3.3.Cost Analysis

The cost of battery design is shown in Table 7 and the cost of mechanical Wig-L-Bug is presented in Table 8.

Table 7: Cost of battery design

Components	Cost
Battery	$322.95
Charger	$36.95
Inverter	$85.00
Total	$444.90

Table 8: Cost of mechanical Wig-L-Bug

Components	Cost
Gears	$195.00
Shafts	$7.50
Bearings	$18.60
Polycarbonate	$25.20
Glue	$7.50
Handle	$26.40
Total	$280.20

3.4. Design Comparison

3.4.1. Battery Design

Firstly, battery design could provide continual power for the Wig-L-Bug compared with the gearbox design. A fully charged battery could support the Wig-L-Bug to work for about 5 hours. Besides, it is much more convenient for the Dental Hygiene Department to operate the battery design. Once the battery system is connected to Wig-L-Bug, there is no need of manual power any more.

However, battery design highly depends on the local conditions. If there is no access to electricity, the battery cannot be charged in time. Then this may negatively affect the work of Dental Hygiene Department.

3.4.2. Gearbox Design

Gearbox design does not need any electricity, and it only requires some manual power input. Therefore, local conditions cannot limit the application of gearbox design. Moreover, there is no need to connect the gearbox design with the Wig-L-Bug. The main part of a Wig-L-Bug is a shaker, and this shaker can mix the dental filling material. In the gearbox design, a shaker has been connected to the shaft. Actually Dental Hygiene Department does not need the Wig-L-Bug any more if they use the gearbox design to mix dental filling material.

However, gearbox design requires continual manual power to mix dental filling material. It is possible to mix just several bottles of dental filling material, but it is quite difficult to provide continual manual power to make the gearbox design mix too many bottles of dental filling material.

4. Testing Procedure and Results

4.1. Testing Procedure

The team initially planned to test the battery prototype by powering the Wig-L-Bug for 4 hours continuously. Considering the Wig-L-Bug was a sensitive electronic device and continuous running might damage the dental device, the team decided to use a 50W light bulb to simulate the operation state. Finally, the 50W light bulb was powered for 4 hours and 45 minutes before the battery drained. The team also determined that it took 9 hours to fully charge the battery from zero percent state of charge. In addition, the team discharged and charged the battery 5 times to make sure the battery and charger were not defective.

The team also tested the mechanical Wig-L-Bug. It was stable when the crank handle was cranked at a speed of 70 RPM. The mechanical Wig-L-Bug mixed the dental filling capsule as well as the electricity powered Wig-L-Bug. Thus, the mechanical Wig-L-Bug is capable of mixing the dental filling material well with manual power input.

4.2.Results

The client took the battery design to India, Mainpat settlement and it turned out to work properly. Our client, Maxine Janis, was satisfied with the battery design. The battery design meets all the requirements and constraints and the project is a success.

The Dental Hygiene Team, with the assistance of Engineering Team 15 made a difference in the lives of the Tibetan people at the Mainpat Refugee Settlement in India this past December. – Maxine Janis

5. Conclusions

In December of 2012, some professors and students of NAU Department of Dental Hygiene wanted to provide dental hygiene service in India but there was no electricity which could be supplied for their device. The team decided to design a battery system for the Department of Dental Hygiene as their power source for the Wig-L-Bug at the beginning of the last December. In battery design, the team mainly used the battery as the power supply for Wig-L-Bug. This battery design is portable in both weight and size, therefore it is quite convenient to transport this battery design. Finally, NAU Department of Dental Hygiene successfully provided humanitarian aid in India in December, 2012. This battery design worked properly, and could mixed dental filling material efficiently.

In this semester, the team attempted to design and build a gearbox design to mix the dental filling material. This gearbox design is quite different from the battery design, and it doesn't need an electric motor to drive the Wig-L-Bug system. The gearbox design mainly consists of the manual crank, steel shafts, spur gears, bearings, and housing. The gearbox design could replace the electric motor in Wig-L-Bug to mix the dental filling material. The total cost of the gearbox design is $280.20, which is much cheaper than the battery design's. However, the team did not have a complete test for the gearbox design, and it would probably work.

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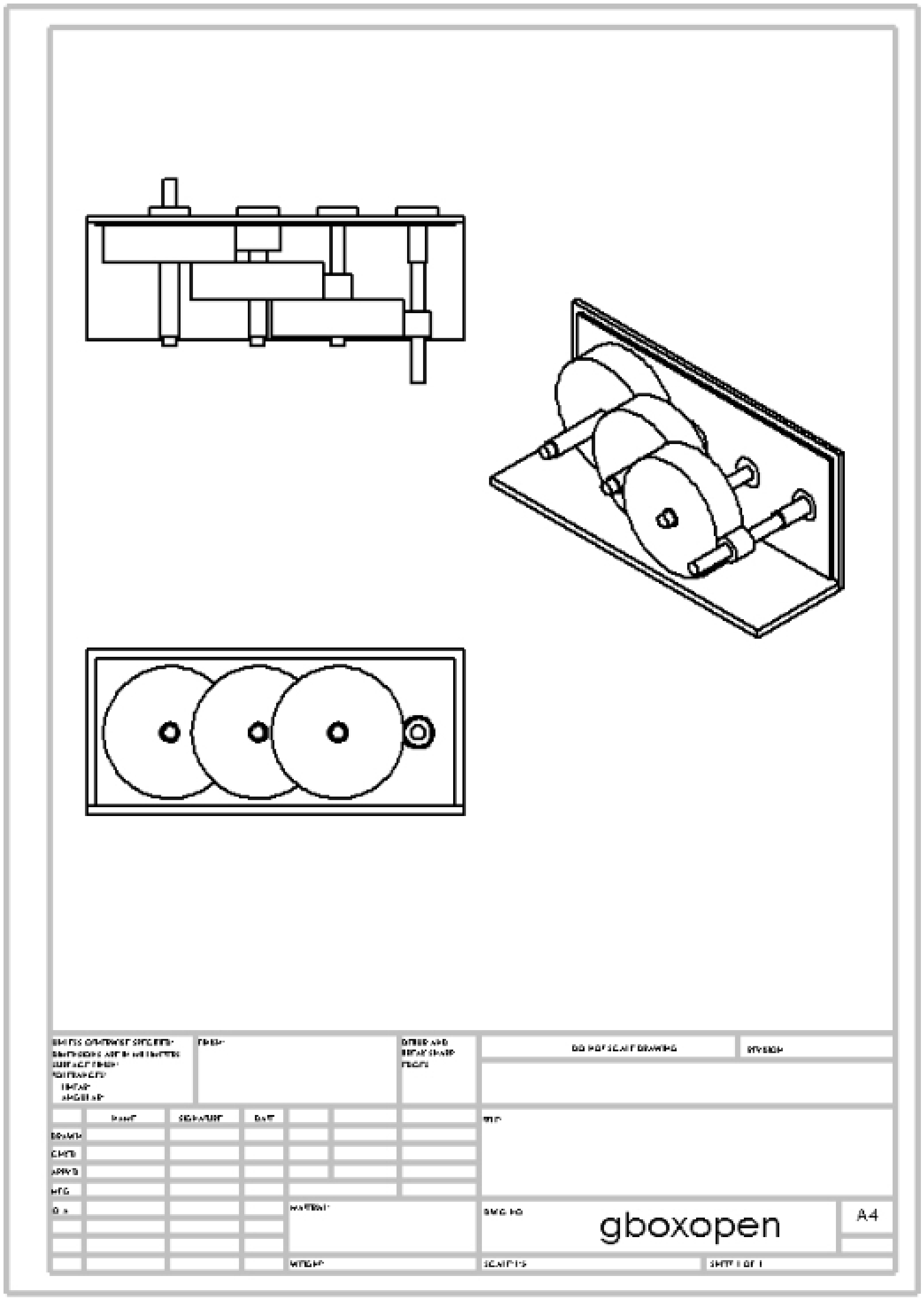
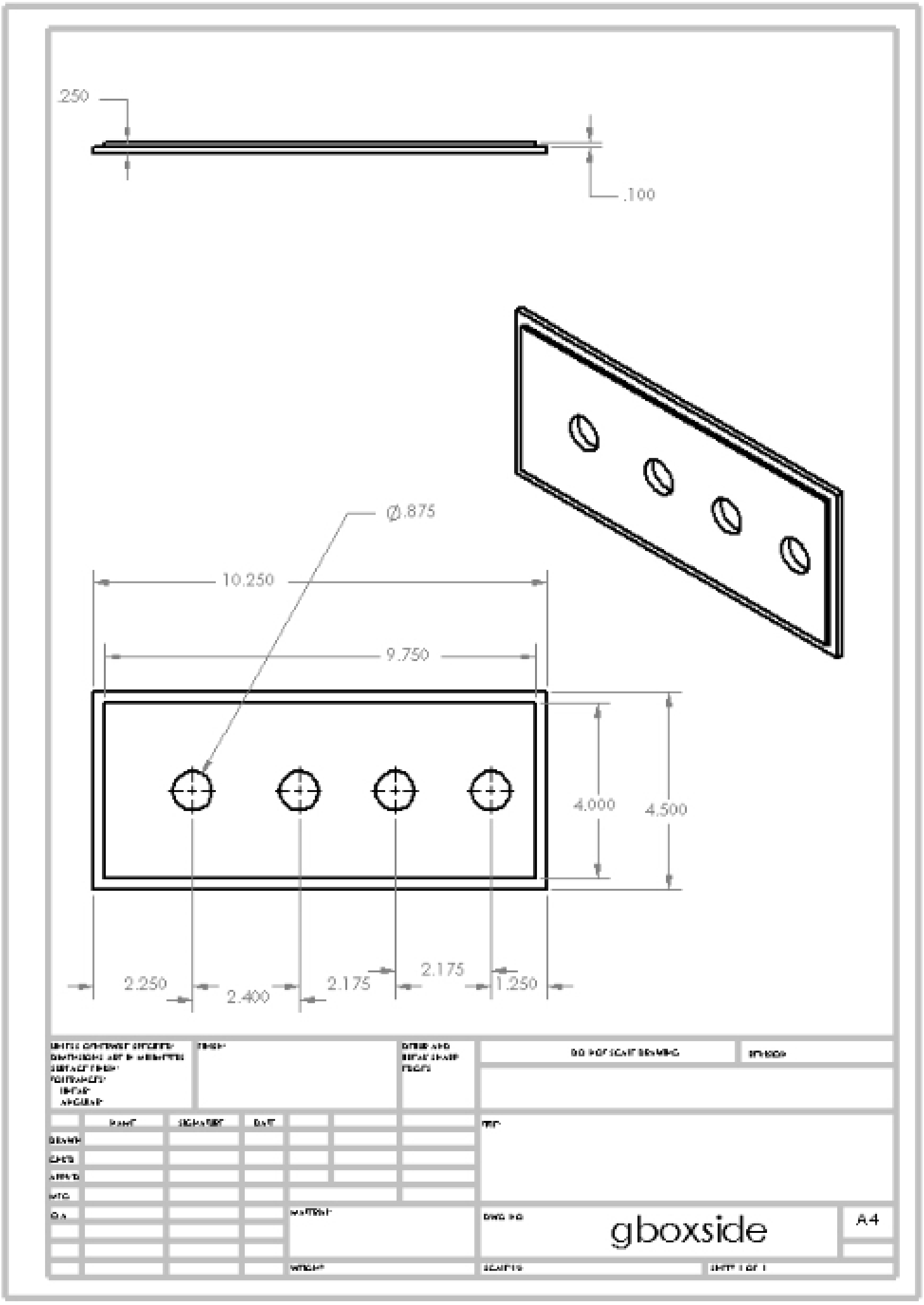
Appendix: CAD Drawing of Gearbox Design

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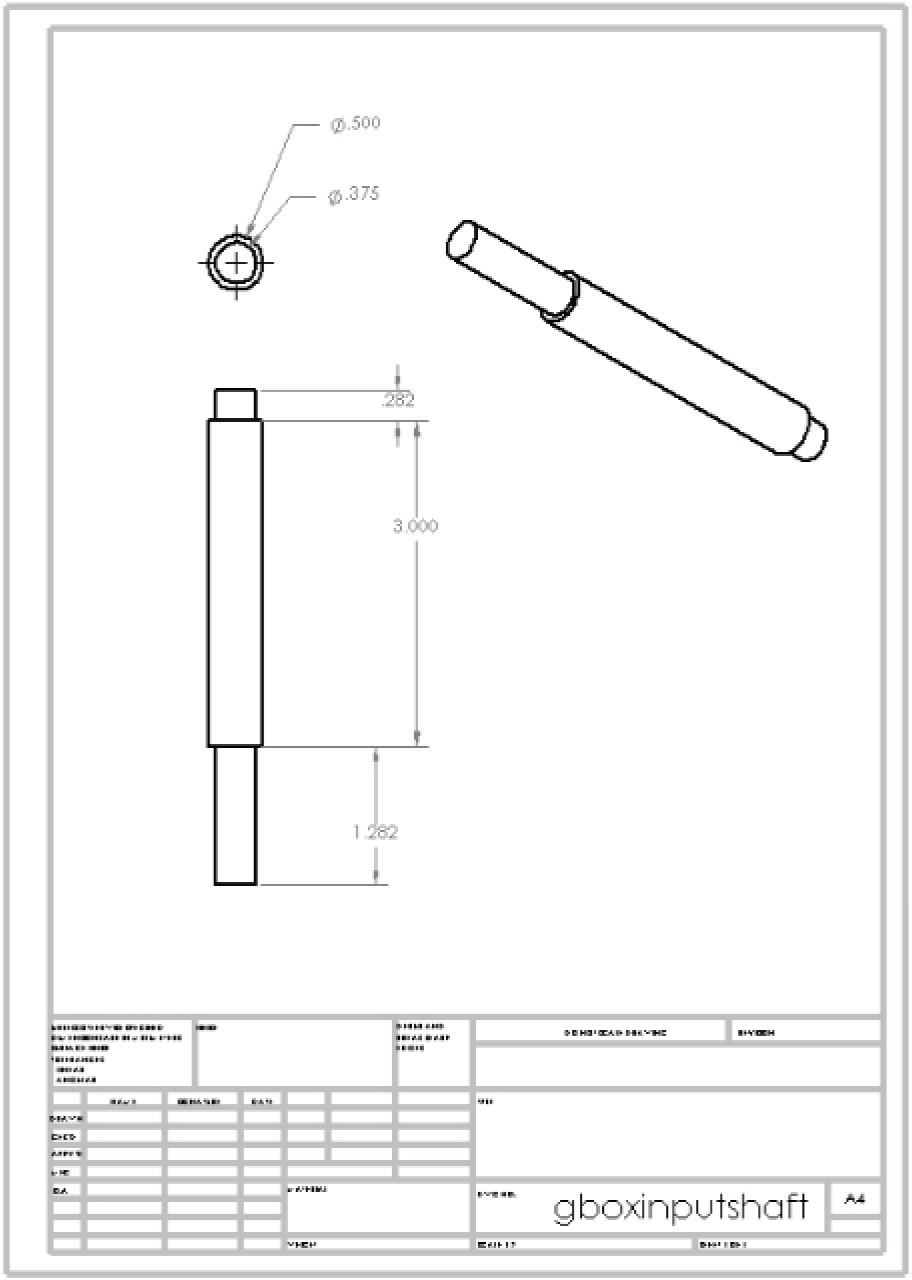

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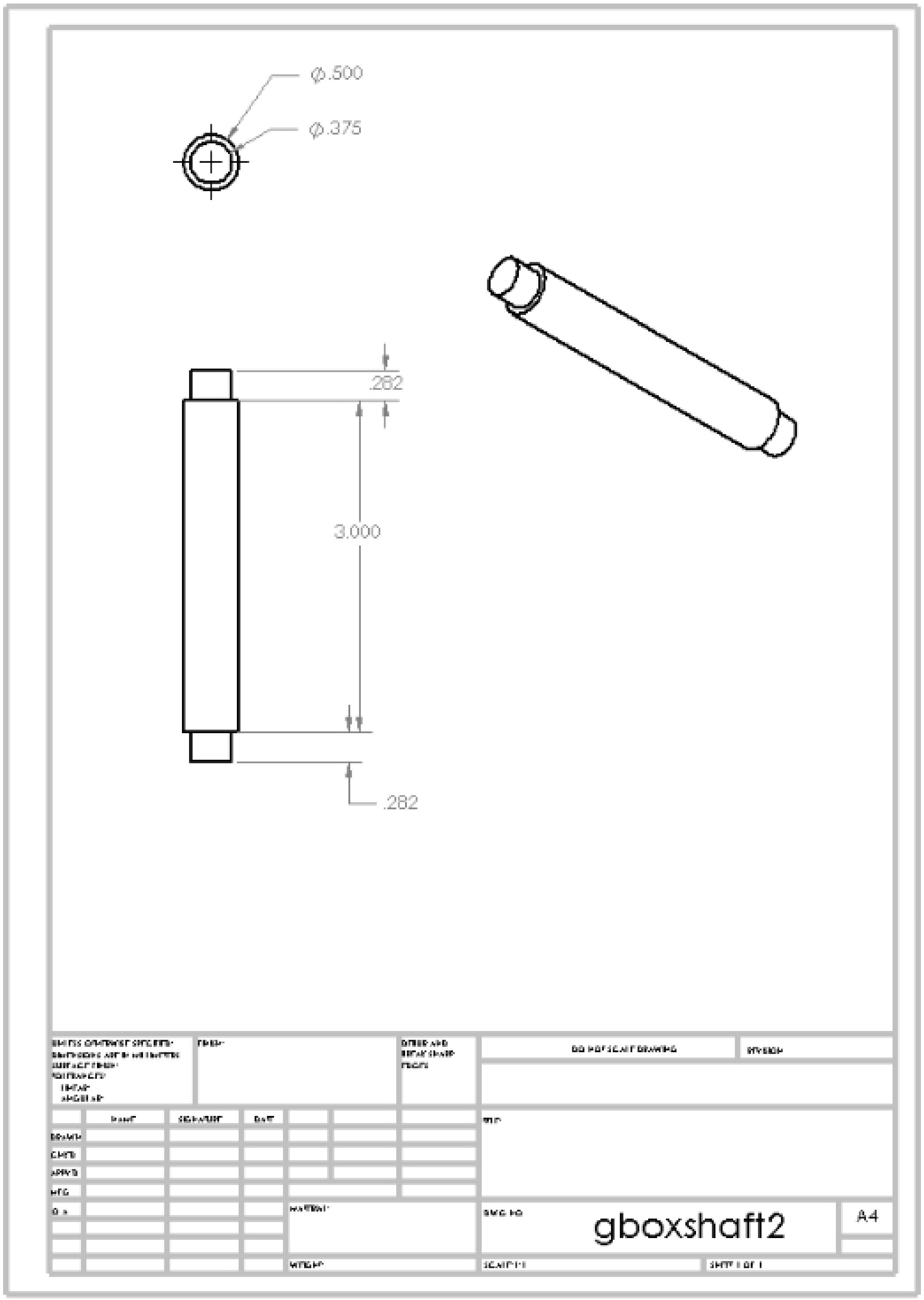
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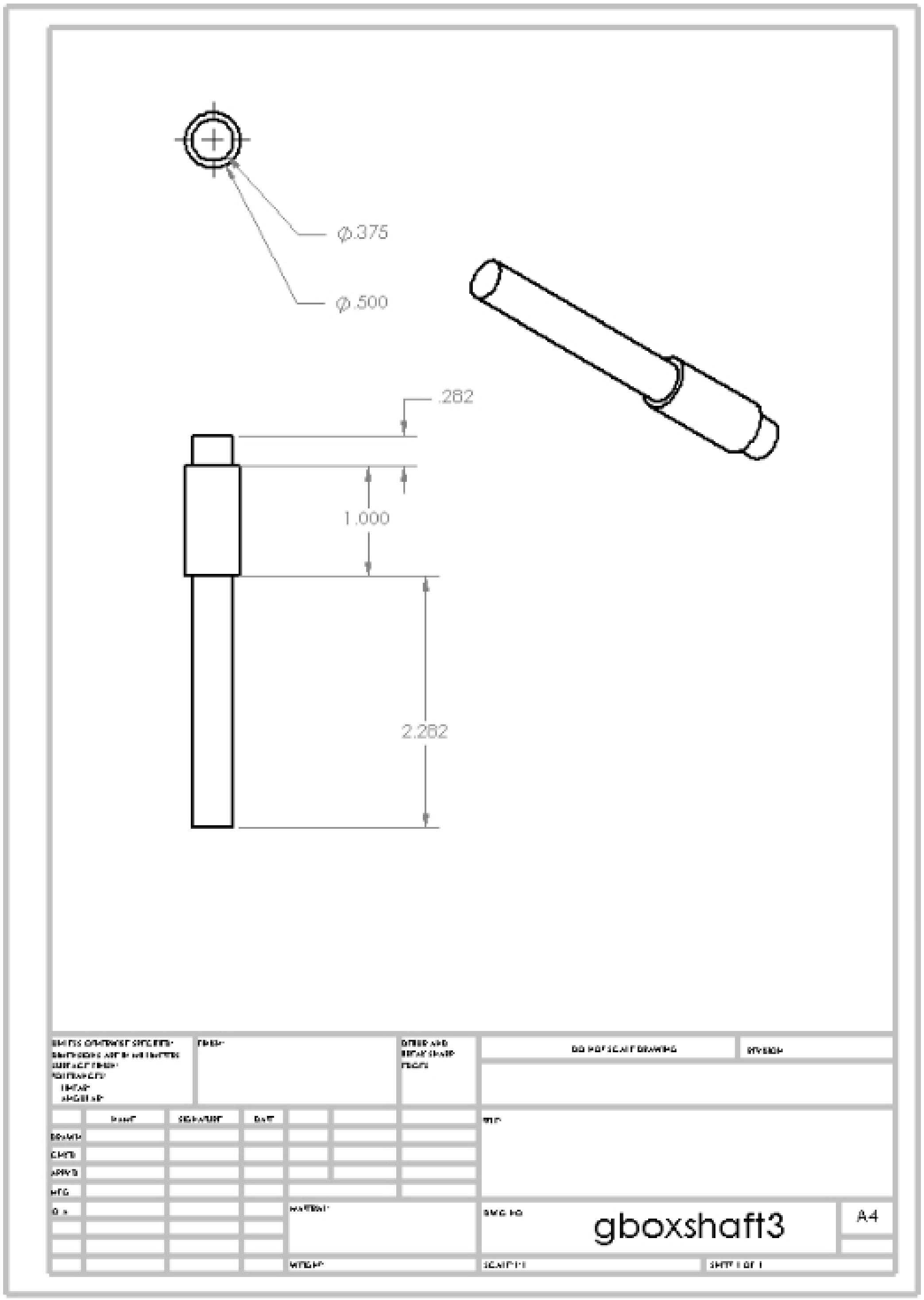

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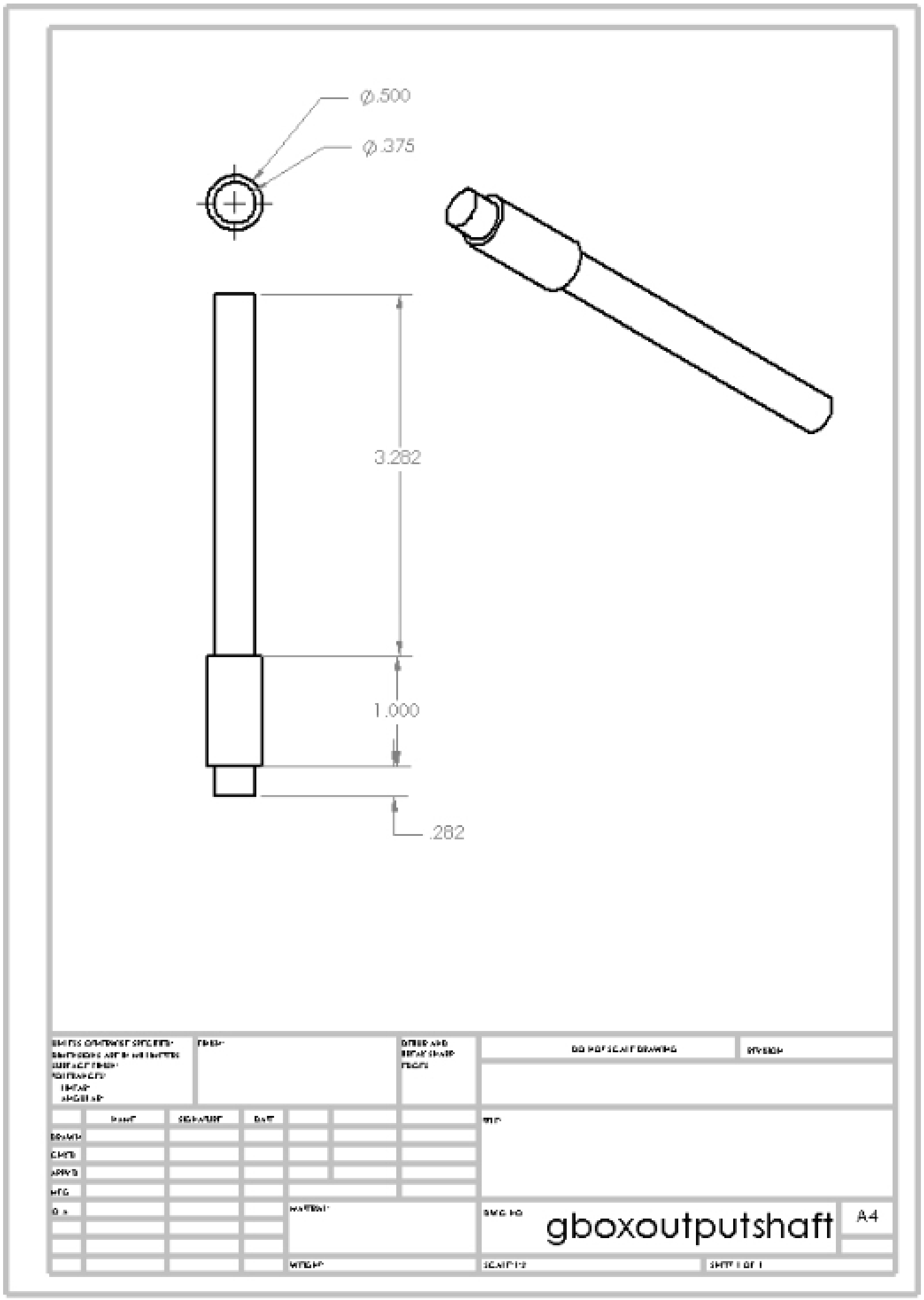
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