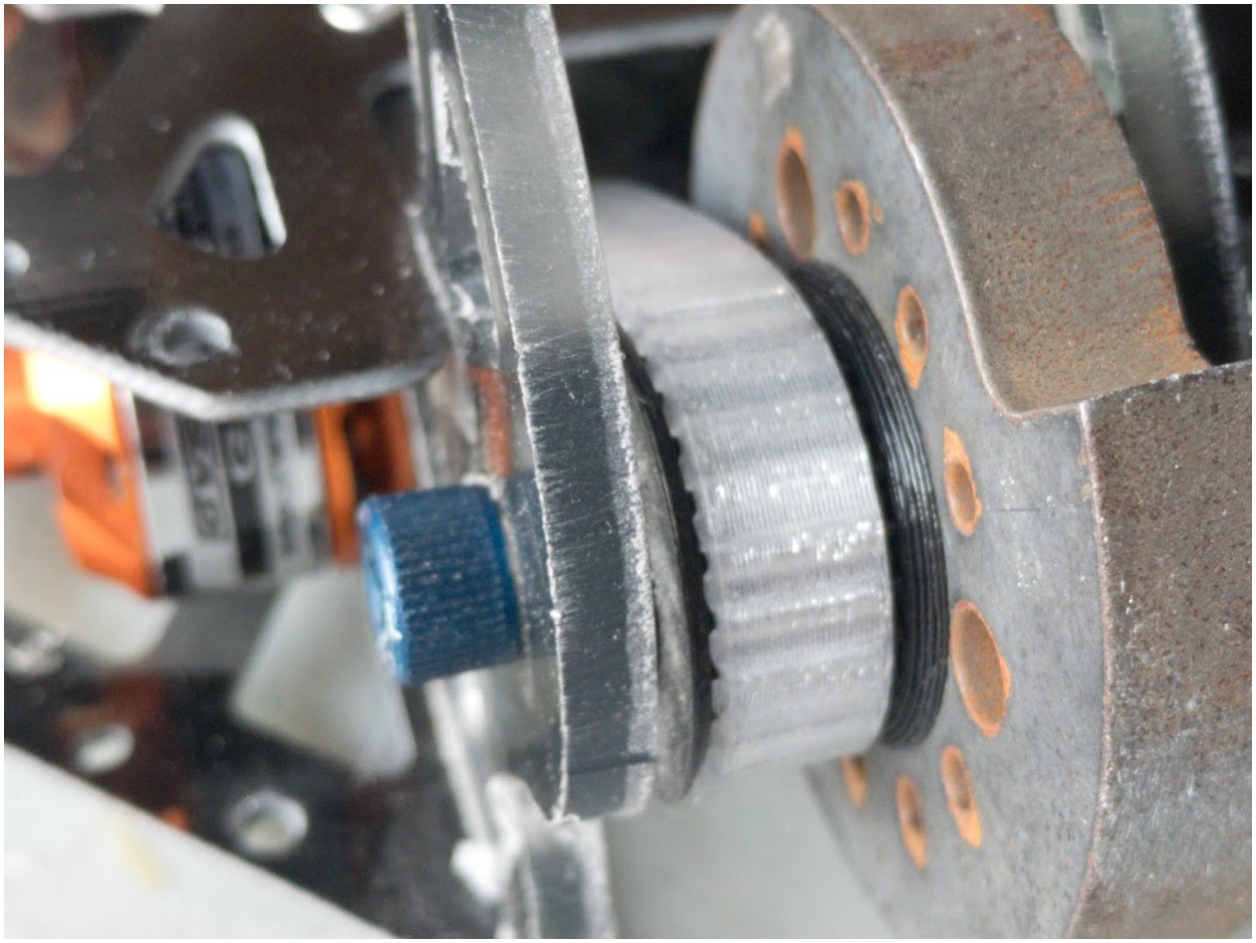
3D Printed Timing Belts



Shown above is an example of a 3D printed timing belt (Germita, 2020).

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Abstract

Due to increasing issues in the supply chain from COVID, labor strikes, and already existing difficulty to supply replacement parts for tractors, farmers are experiencing issues with heavy increases in price for necessary parts and in time for said parts to be delivered. These complications in turn have caused food shortages and other related problems for the everyday consumer. To combat this, a solution to use 3D-printed timing belts, one of the most common crucial parts of a tractor to fail, as a temporary replacement was designed so that farmers are not forced to pay much higher prices or to wait undesirable amounts of time for parts without working. This plan would require the set up of a 3D printer able to use Ninjaflex TPU filament or some other similar material and a database containing different standard timing belt sizes, as well as a parameterized template design for non-standard sizes. After analyzing the cost of both the current situation and the solution, though expensive up front, the proposed solution is estimated to be more cost-effective, especially if used by a local repair shop to supply to all nearby farmers.

Problem Statement

As of the end of 2021, farmers were paying 30% to 50% more for farm equipment - especially used tractors - than they were in 2019 (McCausland, 2021). This is happening as a result of the current scarcity of farm equipment in the market - caused by a series of strikes and supply chain inadequacies. In order to save farmers from paying these rising equipment prices - which would in turn raise the price of their crops and the food we buy at the store - an effort should be made to keep existing tractors in operating condition. Unfortunately, replacement parts are also becoming more difficult to source. Sam Dixon, manager of Shelburne Farms in Vermont, shared his concerns with WCAX. Dixon described issues locating parts for machines essential to daily operations - including a rebuild kit for a hydraulic cylinder and a heater motor (Gaiss, 2022).

Timing belts are among the most common points of failure in a tractor (Piesz, 2020). These belts are often non-standard and difficult to find in local repair shops, and current supply chain disruptions mean that farmers often have to wait much longer than usual for these belts to arrive by mail.

Description of Solution

Rather than repair shops needing to carry non-standard belts for local farmers, or those farmers having to wait for a new belt to arrive by mail, they can 3D print a temporary and inexpensive fix. In order to rapidly recreate 3D models of both standard and non-standard belts, these farmers/repair shop employees will use a parameterized template which will automatically generate a model based on just a few measurements of the original belt.

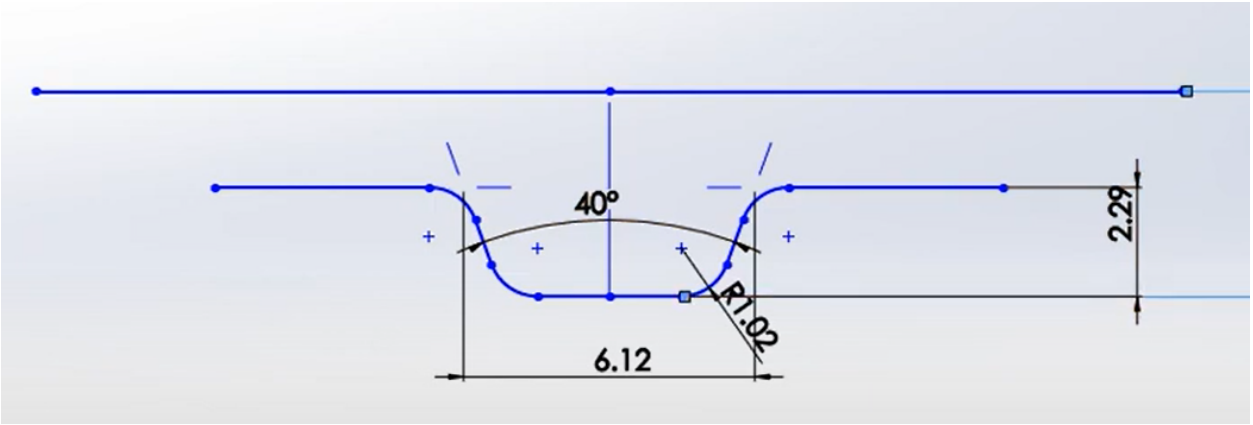

Figure 1. Single Iteration of Timing Belt Tooth

As shown above, often timing belts are modeled with reiterating sections centered around the teeth that mesh into the gears. Length of the overall belt, along with the specifications of these reiterating sections such as thickness, pitch, and number of teeth, will be included in the aforementioned parameterized template so that the consumer only needs to know their own belt's measurements and input the information into the template.

While this printed belt will not be as strong as a belt ordered from the supplier, it will provide a temporary fix until the supplier belt arrives. This will be especially useful in rural areas, where shipping is difficult and slow. It will also mean fewer delays and allow these farmers to continue to operate their equipment. In all, this solution should be able to mitigate the issues caused by supply chain disturbances and allow farmers to more efficiently run their businesses with far fewer obstacles.

Justification of Digital Manufacturing

Tractor belts are flexible, relatively small and simple geometry products made of EPDM rubber and polyester plastic. The teeth of the belt can be patterned in a CAD software and printed to the required dimensions with relative ease. McMaster Carr has many standard tractor belt sizes that can be used as dimension references for the CAD models. Tractor belts can be printed using a TPU filament, such as NinjaFlex 3mm TPU. This filament is both durable and flexible, similar to EPDM rubber. NinjaFlex TPU in particular has a 660% elongation factor, allowing for repeated movement and impact without significant wear or cracking. In addition, TPU has excellent vibration reduction, lending itself well to engine application. By 3D printing these belts with flexible filament lengthwise along the print bed, we can assure that the load will not be applied though the layer lines leading to layer separation. However, with repeated use, the material can stretch over time. This makes TPU 3D printed tractor belts a good temporary replacement for broken rubber belts, but not a long term solution like wire-backed OEM belts.

Benefits to Consumers

Our consumers of focus are farmers. Typically, because farmers live in rural areas, the local part shops do not carry the exact parts a farmer may need. Especially when it comes to tractors, specific belt sizes are needed and may take months to replace due to supply chain shortages. By 3D printing the belt, the farmer will have a quick, temporary fix to keep their tractor running while they wait for their new belt to come in. Downtime will be reduced, allowing farmers to continue working. Looking at the bigger picture, by addressing the supply chain issue with tractor parts, farmers will reduce their downtime, increase their production, and will help combat food-related supply chain shortages as well. This solution will benefit the specific audience of farmers by keeping their productivity up as well as the larger consumer audience by addressing the food supply crisis.

Cost Analysis

As a result of the COVID-19 pandemic and labor strikes sweeping across the world right now, supply-chain shortages are persisting and causing massive shipping delays. According to Goldman economist Ronnie Walker in 2021, “Backlogs and elevated shipping costs are likely to persist at least through the middle of next year” (Cox). In addition, the manufacturing industry has been hit with “tight labor markets, tight transportation markets and overall capacity constraints,” causing farmers to have to wait for weeks for a new timing belt. Supply Chain shortages are not going away anytime soon. Right now in Indiana, the average salary for a farmer is $16.96 per hour (*Farmer Salary in Indiana,* 2022). According to the Central Statistics Office, farmers work an average of 49.1 hours a week (*Bureau of Labor Statistics*, 2022). So, for every day that the tractor is down, the farmer would hypothetically lose $166.55. This is only based on a predicted hourly wage. There are many other costs that fluctuate depending on the time of year and whether it is harvest or planting season. According to John Shutske, researcher at the University of Minnesota, one day of downtime during harvest season can cost between $600 and $900 a day - and up to $5,400 per week just in lost time - which can be catastrophic to farm operations.

A timing belt needs to be the exact right shape, or else the valve and pistons in the engine will hit each other, causing permanent engine damage. OEM timing belts are made of rubber material that includes nylon fiber reinforcement. A TPU 3D printed timing belt does not have fiber reinforcement, making it susceptible to deformation over time. For our solution, we would print the timing belts with NinjaFlex TPU (95A). This filament can print at a speed of 60mm/s and can withstand 17,000 in*lbF/in^3 before deforming, making it a quick and easy replacement material for a tractor belt (*GMB North America,* 2022). One 2 kg (approximately 4.4 lb) roll of NinjaFlex TPU costs $160.00 (NinjaTek, n.d.), and since the rubbers commonly used in timing belts and TPU are roughly the same density we can assume these belts would weigh nearly the same as their manufacturer counterparts (bitfab, n.d.) (Suebel, n.d.). A timing belt weighing nearly 0.3 lb (Mitsuboshi, n.d.) would cost $10.89 in TPU filament alone. A single roll

of filament would be capable of printing nearly 15 belts. However, there is more to this problem than the material alone.

In order to print these belts, these repair shops must order a 3D printer capable of printing flexible filaments. More affordable models can run between $250 and $350 upfront (Dwamena, n.d.). Then, in order to use the parametric model to create these timing belts in CAD, these shops must purchase a commercial license for CAD software. Annual subscriptions to packages such as DS Solidworks, PTC Creo, and Autodesk Inventor can cost between $1,295 and $2,550 per year (Autodesk, n.d.) (GoEngineer, n.d.) (PTC, n.d.). This could mean repair shops are paying as much as $2,900 just to set up for this process, not including the cost of the time spent training shop employees how to use the new software & hardware. Despite these large upfront costs to the repair shop, though, this service would reduce downtime to a day or two as opposed to multiple weeks, saving farmers thousands of dollars by continuing production until their OEM belt arrives. Therefore, farmers may be willing to pay a higher price for these temporary belts if it means a cost savings of many thousands of dollars.

In today's economy with its unpredictable supply chain woes, there is a potential market for a temporary belt printing service. Repair shops must first be convinced that the large initial investment will pay off. Due to the frequency of timing belt failures and the savings of having an immediate temporary replacement, though, we believe that this method could prove to be cost effective.

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