Design and 3D Print Mechanism to Eliminate Clogging in Sewers Caused by Roots to Improve Flow in Qatar

Abstract. The purpose of this paper is to present a prototype designed to solve a common issue that occurs in Qatar sewage systems which explains having unfinished sewers maintenance in most neighborhoods, it is due to clogged house sewers. House sewers are often clogged by many components but roots are the most common, this results in house floods, loss of time, effort, cost and a long shutdown time of the system. Therefore, a new mechanism was needed, studied, designed, and 3D-modeled to physically test its size and functionality and most importantly, solve the main problem of unclogging sewers from roots. Collected data was based on research and interviews with civil and maintenance engineers which led to generating mechanical design concepts using SolidWorks and Ultimaker 3D printers, other concepts included material properties, stress analysis, and environmental considerations. The mechanism was designed particularly to overpower the roots resistance and cut through them, leaving a clean inner pipe and an uninterrupted wastewater flow, and to eliminate chances of flooding. Due to the purpose of this study and the nature of its operation, a stress analysis study was made on the drill head to validate the scenario of fabricating the mechanism using the chosen material.

1. Introduction

Typically, when clogged drain is noticed at home, the first thing that comes to mind is to grab a plunger. Many people do not know that traditional plunging is nearly ineffective in some situations, such as when the house's main sewer line is clogged. If this occurs, significant flooding and plumbing issues throughout the house may be experienced. Drainage pipes transport waste out from sinks, bathrooms, and other fixtures across the property. These lines all connect to the main sewageline. This main pipe transports all waste from houses to the street sewage system. Once the main sewer gets clogged, drains throughout the house stop functioning. A crucial reason of clogged sewers are roots from trees and plants around houses. This project was based on valuable and verified sources for the literature review to gather information and initiate ideas. Sources were from the internet: websites, electronic books, companies' journals, and meetings with civil, and mechanical engineers in Qatar.

2. Background

The richest destination of water and nutrients in soils around houses are sewers due to the dump of waste and wastewater. Roots make their way to sewer lines either from pipe ends or break into the pipe to get the needed nutrients. Once the roots enter the sewer lines, roots either break the pipe or clog it, either way; it is a constraint of household domestic water usage because it can cause floods, downtime, extra expenses, and more complications. Therefore, the most common reason for clogged sewers are roots, especially around houses where trees and other plants are planted. In Qatar, the 6-inch diameter pipes are used in the sewage system which allows enough room for roots to fit inside the pipe and clog it. Before finding a solution to unclog pipes, a clog must be indicated at first. There are the traditional signs to indicate clogs in pipes meaning that the main sewer could also be causing the problem. . This project aims to solve the blockage caused by roots and improve wastewater flow in sewers to avoid floods, water overflow, expensive water bills, and other consequences of clogged sewers. Due to the incompliance that the current solutions offer, a new mechanism was needed to shred roots and open the closed channel. There are three common methods of cleaning clogged roots which are somewhat effective, but all have a drawback that raises the need for a new mechanism with fewer impacts on the people, environment, and finances.

3. Problem Statement

Like any mechanical system, sewers require maintenance procedures to ensure clear and uninterrupted waste flow of the system. A critical problem affecting the effectiveness of sewage handling is block of flow by various objects such as build-up grease, debris, foreign objects, or treeroots. Almost all houses in Qatar have planted trees in the yards and usually less maintenance is performed for sewers unless there is a damage. Roots are a common cause of blocked sewers and are an important part of a plant, normally grow underground and follow or extend to where there iswater i.e., a small crack or opening in a sewer line will attract roots growth due to high amount ofnutrients. When roots are attracted into the sewer, they multiply and eventually clog pipes and therefore cause block of flow or overflow due to the flow blockage. As a result, household use is affected due to downtime and other reasons. This project was to investigate, Design, and 3D Print a mechanism to unclog 6-inch house sewers. This project also includes a basic maintenance and testing measures to ensure the best quality of the mechanism in case it was implemented and fabricated. This mechanism suggests the new prototype design which combines the pros of existing solutions and eliminates the cons. The report also states a scenario and basic considerations for future implementation of the idea.

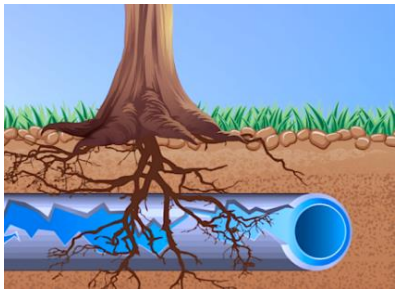


Figure 1. Roots in Sewers Pipes

4. Methodology

This part of the report explains the methodology of one of the major sections of this project,which is the design; many design considerations were considered which will be addressed below. Design concepts were generated, specifications were set, and then the designing phase started.

5. Technical Approach

The proposed design was dimensioned to fit and operate easily inside 6-inch sewers. SolidWorks Software was used. After the research and constructing an objective and criteria table, the design target specifications were defined. To identify the target specifications, research was made on existing solutions to unclog roots from house sewers to create a mechanism combining the pros and eliminating the cons. It was decided that the new mechanism consists of seven components.

6. Generating Design Concepts

One of the existing solutions of unclogging sewers from roots is the Snake Method, in this method the operator pushes a flexible shaft through the pipe, an extracting head is attached at theend of the flexible shaft, the head will perform a clamping mechanism, the roots then will get caught to the head, the operator will retract the shaft from the pipe to clean the head and repeat theprocess till the pipe is unclogged. The Snake Method is effective, yet the procedure can take up to 5 hours to finish. The proposed design is a modification to the Snake Method, attaching an inspection camera and designing a drill head to shred roots will speed up the processof opening the clogged flow. The generated design was made to the following characteristics: Easeof movement and use, eliminate shaking (provides steadiness) to prevent the pipe from breaking,portable, eco-friendly, fit for pipe safety and dimensions, easy to clean and sanitize, effective in cutting roots and opening the flow, provide external manual grip and control for operator, visibilityand monitoring inside the sewer, time saving, moderate effort, noncorrosive material, hollow insides for a lightweight prototype. All seven components were required for their function and role in this project which is explained below.

This was a crucial part to the project as it was challenging to generate a new design. Designingparts was done using SolidWorks Program. Parts were designed based on the estimated dimensions while considering the pipe diameter of 6 inch.

Component	Function
Casing	• Enclosing the inner components, casing is the foundation which has other components were built and assembled on • Casing is the connecting component between the drill head and flexible shaft
Drill head	• Used to shred and cut the roots that are clogged in the sewer withthe attached blades • Inspection camera will be inserted in the middle of the drill head
Wheels	• Wheels allow the mechanism to slide inside the pipe providing protection to the inner pipe and smooth movement. Four wheels were designed and printed to provide the smooth movement on the four sides of the casing
Wheels shaft	• Shaft of wheels are designed for the purpose of holding the wheels in place by attaching them to bearings so they function correctly
Inspection Camera	• Attached to the tip of the drill head where it has a circular holedesigned for it • Provides visibility and monitoring option for the inside pipe
Flexible Shaft	• Used to provide manual control of inserting it into the sewer and how deep it should go
Support block	• A block designed to contain and hold the flexible shaft to provide steadiness and support while the shaft rotates

7. Design Parts using SolidWorks

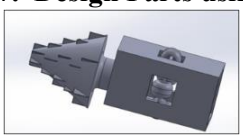


Figure 2. Mechanism Body

The design phase started with a couple of sketches until the best design of each part was constructed and finalized. SolidWorks was used due to its ease of use and built-in features that were needed later for a simulation study forthis 3D model. The designed components were: Drill head and blades, Casing, Wheels and wheel shafts, Support block for flexible shaft. The blades were designed to be sharp, pointy, and short. The blades are 2 mm in thickness with 45^{o} degrees chamfered ends, which gives the blades the sharpness needed to. The drill head holds 30 evenly distributed blades; divided over 5 rows, each row contains 6 blades rotated 45^{o} from the row before it. As a result, providing 360^{o} coverage around the drill head.

Each designed part was assembled to build up the mechanism. The totaldimensions of the assembly are the following:

1- Maximum Diameter (height and width): 14.5 cm
2- Maximum Length: 40 cm

8. Results

This section includes all processes after the design was complete such as 3D printing, assembly of parts, testing, maintenance plans, and stress analysis for the most effected parts from forces and roots resistance.

8.1 3D Printing Approach

Since it is a prototype to new mechanism, the main purpose was to present the new design of physical prototype to observe and partially test it. The purpose was to showcase the new mechanism and if the dimensions will succeed to fit inside 6-inch diameter sewers. It was decided that the project would be executed by the help of 3D printers. Since it is a new suggested design, an innovative technology was

preferred as a safer option.

8.2 Selecting Parameters

Custom made parameters can be set for different materials, where temperature and speed can be chosen and monitored. In this project, no specific parameters were chosen but there are recommended specifications set by default for PLA filament. The parameters selected for this project are the default settings. Speed and scale of printing can be adjusted to save time for larger parts which take the most time. At the start of the printing phase, smaller scales were chosen as a faster test run to make sure that the printer will not have an issue generating the G-code and to ensure that there is no issue in the STL file.

8.3 Material Selection and 3D Printing

For this mechanism, PLA material was chosen to print all parts for the following reasons:

1. Polylactic acid, or PLA, is by far the most popular FDM 3D printing material
2. Available and relatively inexpensive
3. Comes in hundreds of vibrant colors and blends
4. One of the eco-friendliest options for 3D printers
5. Available in soft and hard forms
6. Familiarity with the usage

Material specifications of PLA filament were chosen from Fill30 Pro brand which is a common company to produce 3D printer filaments. The filaments have a few specifications such as diameter, color, weight, print temperature, bed temperature. The specifications vary depending on the material and filament. Each filament material such as PLA, can have multiple specifications which include:

1. Material: PLA
2. Diameter: 2.85 mm
3. Colors: White, Red, Blue, Orange (chosen based on availability in classroom 5.120)
4. Weight: 750 g
5. Print Temperature: 180 - 210 ºC
6. Bed Temperature: ± 35 - 60 ºC

9. Real Life Mechanism Scenario

9.1 Material Selection

Sewer pipes are humid, poorly ventilated, and make good housing environment for bacteria. Because of brass and copper properties, they are used in less-fictional applications. The recommended metal for the proposed solution is 304 Stainless Steel; this grade of stainless steel is used in industrial, medical and household application. 304 Stainless Steel is the most common form of steel due to excellentcorrosion resistance and its ease to be sanitized. The following sections will discuss the best suitable material for each part of the design.

9.1.1 Casing

The casing is what holds all the components together, it needs to hold the weight, and be able to sustain the forces from other components. The casing consists of four -10mm thick- walls. According to the 304 stainless steel mechanical properties; each 10 mm plate has tensile strength upto 750 MPa (108778 Psi), and proof stress of 230 MPa. Stainless steel in general has high densitywith an average of 7.8 g/cm^3 by using 304 stainless steel for the casing; no additionalprotective layer will be needed. Stainless steel is one of the easiest metals –after gold and silver- to be sanitized.

9.1.2 Drill Head

The drill head will be the first part of the mechanism that will impact with the roots rotatingat a maximum speed of 2000 rpm. The drill head will be responsible in cutting and shredding through the roots, in very humid and unventilated circumstances. Tree roots in the sewer system have the same physical properties of wet wood. The roots in sewer system have has a very low hardness (<50 KN) and toughness <1 N.m. The high tensile strength and proof stress of 304 stainless steel, rotating at maximum speed 2000 rpm will shred and drill through the roots with minimal resistance. A stress analysis study was made to ensure that the drill head will withstand the objected forces.

9.1.3 Wheels

The high-speed rotation and the process of eliminating roots will cause a high vibration within the mechanism. Silicone wheels are required to provide grips with the interior walls of thepipe. Silicone is type of rubber; because of its high elasticity the rubber silicon wheels provide high friction with the touching surface. In addition to the wheels support, they will make the mechanism movement even and leveled, and prevent damages that may occur from vibration androtation.

9.2 Motor and Power Source

Sewer systems can be accessed through manhole, usually located outdoors and far from any source of power. The mechanism is portable; all components run on rechargeable batteries. The following table will compare most 3 suitable portable drill motors with respect to their Rpm,power, & torque.

Name	Rpm	Max Power (Nm/S)	Torque (Nm)
DEWALT 18V XR	550 - 2000	460	27
BOSCH PSR 18 LI-2	0 - 1350	370	38
WORX WX372	0 - 1800	400	50

Source: Author

Shredding the roots require high rotational speed and high power. The sharp edges of thedrill head will cut its way through the roots while rotating in high speeds. Dewalt 18V XR provides the highest speed while being cordless and portable at the same time.

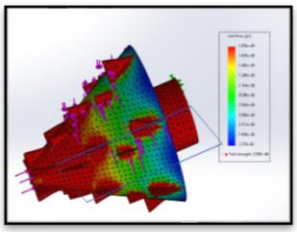


Figure 3. Stress Analysis

9.3 Flexible Shaft

The flexible shaft is what delivers the rotational movement and power fromthe motor to the drill head. Flexible shafts allow the mechanism to enter the sewer pipes from tightconfined spaces such as manholes; it can deliver up Rpm with maximum torque of 550 Nm.

9.4 Pipe Inspection Camera

The process of eliminating roots in sewer pipes happens underground. The camera will give a live feed of the operation. The drill head has an opening at its end, this hole is designed to hold 23mm pipe inspection camera, and this will allow the mechanism toprovide a live feed of the process.

9.5 Mechanism Specifications

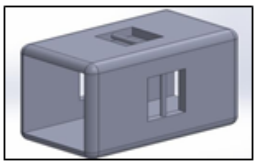
Height (cm)	Width (cm)	Length (cm)	Power (Nm/s)	Torque (Nm)	Max Rpm	Process Duration (hr)	Interior Visuals	Portability
14.5	14.5	40	460	27	2000	0.5 - 2	Yes	Yes

The table above shows the mechanism specifications and durability. The system is 14.5x 14.5 Cm, which will give 5 mm clearness in total for the shreds to escape behind. The drill head will be rotating at a maximum of 2000 Rpm and with a power of 460 Nm/S; the mentioned power with the drill head design will give the ability for the mechanism to shred its way through the rootsto improve the flow of the wastewater in sewer pipes.

10. Recommendations

10.1 Design Modifications

10.1.1 Casing



The designed mechanism has sharp corners; sharp corners absorb the forces with very minimal distribution of the forces. Converting the sharp corners to fillet corners will significantly improve the forces distribution along the casing, which will expand the life expectancy of the casing and the mechanism in general.

Figure 4. Casing

10.1.2 Drill Head and Blades

The drill head and blades are what absorb the first direct impacts while rotating at a speed up to 2000rpm. thecone shape naturally distributes the forces evenly along the head. Since the blades will shred the roots and get impacted from the root's resistance, the blades should be welded with fillet joint withthe head, fillet welding adds strength, and extra material to help keep the blades from breaking.

11. Conclusion

This work did aim to solve clogging in sewer pipes caused by tree roots. A new mechanism was designed and a prototype was 3D printed, to give a visual on the design. The 3D printed prototype successfully proved that the dimensions of the design are fit t go inside 6" PVCsewer pipes. The designed mechanism will go inside sewer pipes and the designed drill head willrotate to shred and cut its way through the tree roots. The mechanism design gives a life feed visual from inside of the sewer pipe using 2mm pipe inspection camera that can be implementedon the beginning of the drill head. The project was successful in the end of the mechanism. The proposed design succeeded the theoretical and practical aspect. Simulation has been done on specific material to study the Impacton the most effected part with specific forces, loads, stress analysis and still passed the impact during the highest rotating speed.

12. References

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