Planned Helical Rack Gear Transmission for Slider Driven by Y-Axis Cremona Construction Frame on 3-Dimensional Concrete Printing Machine

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Abstract: 3D concrete printing (3DCP) is an innovative method of 3 Dimensional concrete cast printer in the civil building construction industry that can optimize process time &cost, design flexibility, and reduce errors and is environmentally friendly. This 3D *printing* machine is of the cartesian type there are 3 frames as the direction of movement, namely the X, Y, and Z axes. Construction of the Y-axis frame acts as a load support for the X- and Z-axis frames and as the foundation of the X - Z axis frame drive slider in the Y-axis frame. This Y-axis frame is the base of the overall construction of the machine. 3D printing technology (3D Printing) plays a fundamentally important role in the printing process. To satisfy these demands, preparations are being made for the choice of the Helical Rack & Pinion Gear transmission component, which will be used as a Y-axis slider driver for 3D printers for civil structures. After doing the investigation, it was discovered that a Y-axis slider driver for 3D printers (3D Printing) for civil buildings may be made using a Helical Rack & Pinion Gear transmission element with the following specifications: 1.25 module and 20° helix angle.

1 INTRODUCTION

A 3D printing machine for civil buildings is one of the projects that this year's Manufacturing Technology study program participants will create. The transmission element plays a crucial part in the molding process since it affects things like precision, acceleration, and load-bearing strength. In order to fulfill these requirements, planning is done for the selection of the appropriate transmission element to be used as a Y-axis slider driver for 3D printers for civil buildings.

Planning the transmission of helical rack and pinion gear is important because it has a direct effect on the movement of the 3D concrete printing machine that will be made. These factors include accuracy, convenience in the control system, and the strength to withstand the load on the Y-axis slider. What is interesting here is that there is a discussion about the method of aligning the connection between the rack gears, which is very vital for the continuity of the movement of the relationship between the helical rack and helical pinion gear.

The plan is to select what transmission elements are suitable for use on the 3D printing machine, which will be made based on predetermined criteria.

Thus, the purpose of this study is to serve as a form of planning for applying helical rack and pinion gear transmission elements in 3D concrete printing machines.

2 METHODOLOGY

The stages of the research were as follows:

a. Knowing the fundamentals of planning the selection of transmission elements for the Y axis slider drive
b. Recognizing issues with the transmission element for the Y axis slider drive

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c. Review and choose the appropriate transmission element to use as a Y-axis slider drive
d. Perform calculations on the geometry and strength of the gear that will be used as a transmission element for the Y-axis slider drive
e. Visualize the installation of the Helical Rack & Pinion Gear transmission element as a Y-axis slider drive.

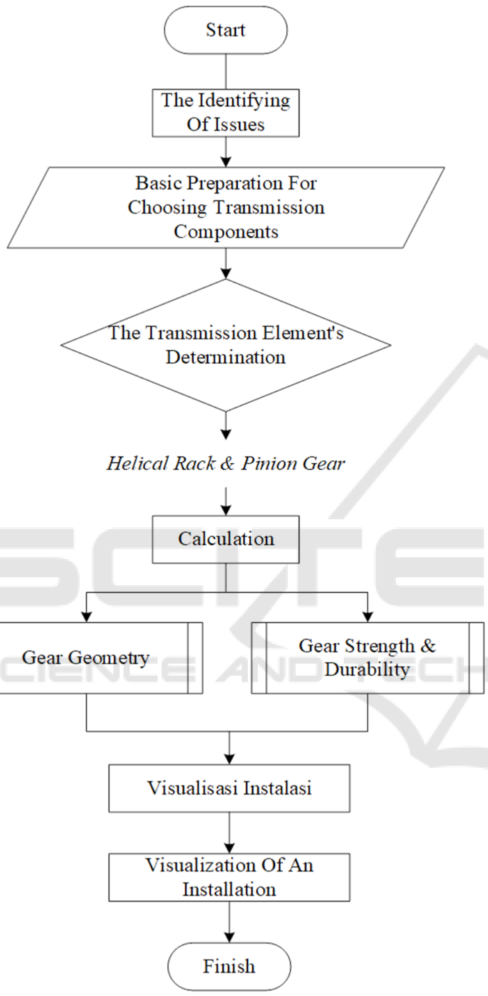


Figure 1: Flowchart for Y-Axis Slider Transmission Element Selection.

3 FINDINGS AND DISCUSSION

3.1 Needs

At this stage, identification of the needs for the Y-axis slider driving transmission element is carried out on the 3-dimensional (3-D printing) building casting machine that will be made. The determination of this need is based on the results of the discussions between MEC 2019 students and the head of the Manufacturing Technology study program. Therefore, a list of demands is made in Figure 2 below, which one D is Demand and W is Wishes.

No.	Demands	Priority
1	**Making**	
	Is possible in the Polman workshop.	W
	Utilizes numerous common parts	D
2	**Assembly**	
	Disassemble-Install	D
	Simple Assembly Method	W
3	**Maintenance**	
	Easy Maintenance	D
	Easy Fix	D
	Low Maintenance and Repair Cost	W
	Easy to clean	W
4	**Marketing**	
	Needed for Civil Development	D

Figure 2: Demand List for Transmission Elements for Y-Axis Slider Drive.

3.2 Basic Preparation for Choosing Transmission Components

Planning the selection of transmission components for the Y-axis slider drive is based on Knowing the load received, the functional style, The installation place are all examples of knowledge.

Figure 2 above is a design of the construction of a 3-dimensional (3-D) concrete printing building casting machine that will be made. This design has gone through several rounds of consideration, which ultimately adhere to the principle of simplicity by prioritizing functions that are expected to run properly and correctly.

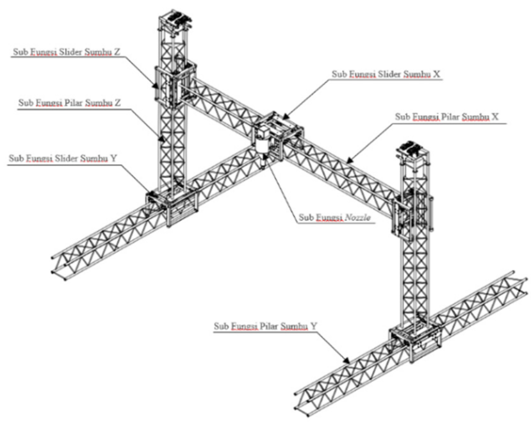


Figure 3: 3D printing machine construction design for civil buildings.

The load that was applied to the Y-axis slider is broken out in Figure 4

No	Component	Weight	Amount	Total Weight
1.	X-Axis Pillar	115 Kg	1	115 Kg
2.	Z-Axis Pillar	80 Kg	2	160 Kg
3.	X-Axis Slider	70 Kg	1	70 Kg
4.	Z-Axis Slider	70 Kg	2	140 Kg
5.	Nozzle	30 Kg	1	30 Kg
6.	Motor	2 Kg	5	10 Kg
7.	Weight Balancer	57,5 Kg	2	115 Kg
Amount				640 Kg

Figure 4: Specifics of the Load that Y. Axis Slider.

The Y-axis slider drive transmission element must be capable of moving a load weighing 640 kg, as shown in Figure 4 above.

3.3 Alternative Selection for the Transmission Element

Planning for the selection of transmission elements is based on observations made on existing 3D printing machines made in Russia and then evaluated (additions and subtractions).

No.	Alternative	Advantages	Disadvantages
1.	 *Rack & Spur Gear*	• Smooth, quiet, and vibration-free • Stronger • *High load-carrying capacity*	• Less expensive to produce than helical gear • Requires lubrication due to increased friction
2.	 *Ball Screw*	• Higher Accuracy Quality • Less Friction (Cooler Temperature) • More efficiency (*requiring less torque – smaller motor*)	• The highest price • Ball bearings cost a little more than lead screws • Require more lubrication.
3.	 *Helical Rack & Pinion Gear*	• Smooth, quiet, and vibration-free • Stronger • *High load-carrying capacity*	• It requires lubrication because friction is higher • it is more expensive to make than spur gear

Figure 5: Explains the construction and operation of the transmission element.

Figure 5 is provided below so that you can learn more about the design and operation of different transmission elements that can be employe

The benefits and drawbacks of each potential Y-axis slider transmission element are listed in Figure 6

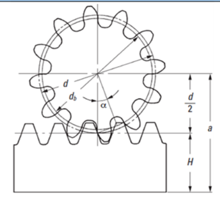
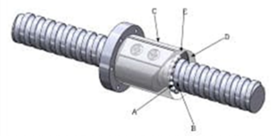
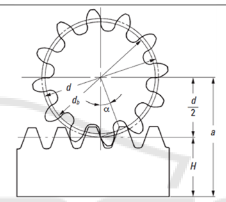
No.	Construction	Work Principle
1.	 *Rack & Spur Gear*	It functions by converting the circular pinion's rotating motion into linear motion on the rack.
2.	 A: Steel ball B: Screw shaft C: Ball nut D: Seal (both sides of ball nut) E: Reciclationparts (return tube, etc.) *Ball Screw*	It transmits the load via a ball bearing flowing in a helical channel, much like a lead screw does.
3.	 *Helical Rack & Pinion Gear*	It functions by converting the circular pinion's rotational motion into linear motion on the rack at a specific helix angle.

Figure 6: Lists the advantages and disadvantages of substitute transmission components.

3.4 Helical Rack and Pinion Gear Calculation

Calculation of Helical Gear and Helical Rack ,there are Torque $T= (F_u\, d_w)/2000 = 0.024$ kgfm=0.235 NM *and* Tangential Speed $V = d_w\, n/19100 = 5.187$ m/s

Types of Gear	Tangential Force, F_u	Axial Force, F_a	Radial Force, F_r
Helical Gear	$Fu = \frac{(1.95x10^5)(P)}{d_w\ (n)}$ $= \frac{(1.95x10^5)(0.75)}{d_w\ (3000)}$ $= 1.475\ kgf$ $= 14.464\ Nm$	$Fu \tan\beta$ $= (1.475)(0.363)$ $= 0.535\ kgf$ $= 5.246\ Nm$	$Fu\ \frac{\tan\alpha_n}{\cos\beta}$ $= (1.475)\frac{0.363}{0.939}$ $= 0.570\ kgf$ $= 5.589\ Nm$

Figure 7: Calculation of Helical Gear and Helical Rack Strength and Durability.

The geometry calculations for the Helical Rack and Helical Gear that will be used on the Y-axis slider are shown in Figure 8.

No.	Item	Gear	Rack
1.	*Normal Module (m_n)*	1.25	1.25
2.	*Normal Pressure Angle (α_n)*	20°	
3.	*Helix Angle (β)*	20°	
4.	*N. of Teeth & Helical Hand (z)*	25 (L)	336 (R)
5.	*Normal Coefficient of Profil Shift (x_n)*	0	-
6.	*Pitch Line Height (H)*	-	26.17
7.	*Radial Pressure Angle (α_t)*	21.106°	
8.	*Mounting Distance (a_x)*	42.81	
9.	*Pitch Diameter (d)*	33.280	-
10.	*Base Diameter (d_b)*	31.016	-
11.	*Addendum (h_a)*	1.25	1.25
12.	*Whole Depth (h)*	2.812	
13.	*Outside Diameter (d_a)*	35.78	
14.	*Root Diameter (d_f)*	30.156	

Figure 8: Geometric Calculations for Helical Gear and Helical Rack.

The findings of the strength and durability calculations for the Helical Rack and Helical Gear that will be used on the Y-axis slider are shown in Table 6. If known: P = 0.75 kW (Panasonic AC Servo Motor 750 W), N = 3000 rpm (Panasonic AC Servo Motor 750 W) and D_w = 33,030 mm

3.5 Installation of Helical Rack and Pinion Gear

3.5.1 Installation of Helical Rack on Y-Axis Pillar

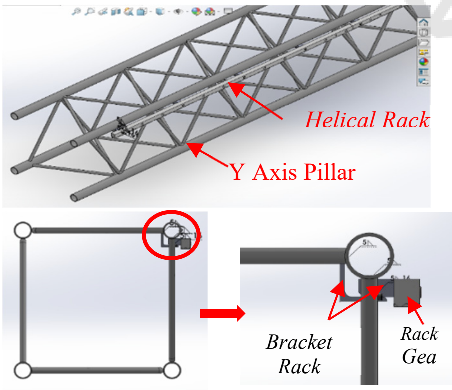


Figure 9: Installation Of Helical Rack on Y-Axis Pillar.

The installation of helical rack gear on the Y-axis pillar using by electric welding, whith two rack gear brackets are attached to the Y-axis pillar.

3.5.2 Installation Helical Pinion Gear on Y Axis Slider

The helical pinion gear installation on the Y-axis slider is shown in the visualization above. The servo motor is mounted to a plate that serves as a motor bracket on the Y-axis slider, and the motor is coupled with the shaft of the helical pinion gear.

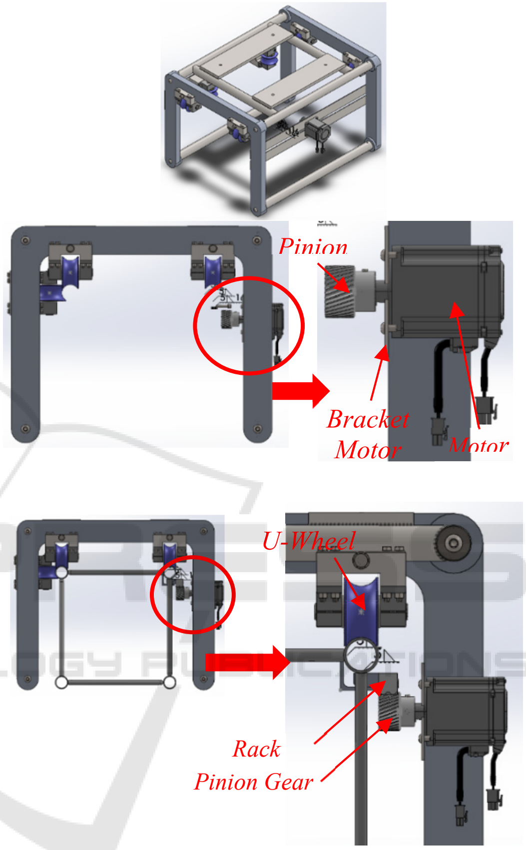


Figure 10: Helical Pinion Gear Installation on Y Axis Slider.

3.5.3 Installation of Helical Rack & Pinion Gear on Y-Axis Slider Transmission

The installation of Helical Rack & Pinion Gear on a Y-axis slider is shown in the visualization above. Using electric welding, two rack gear brackets are attached to the Y-axis pillars. The servo motor is mounted to a plate that serves as a motor bracket on the Y axis slider, and the motor is coupled with the shaft of the helical pinion gear

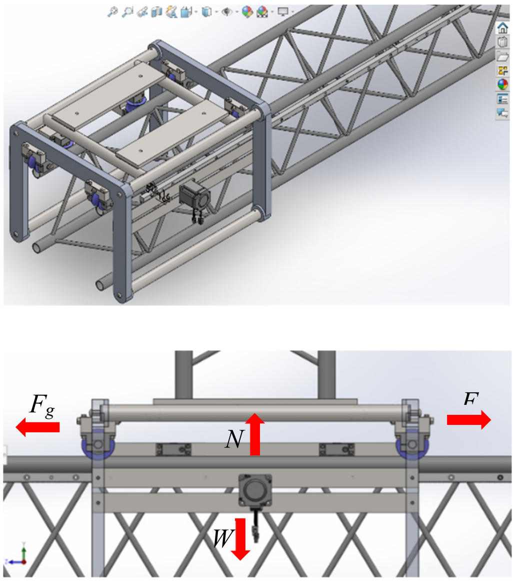


Figure 11: Helical Rack & Pinion Gear Installation on Y-Axis Slider Transmission.

The U profile wheel (U-Wheel) serves as a counterbalance to the servo motor on the other side on the Y-axis slider. The U-Wheel also aids in preventing the slider from tipping over on one side, which would be heavier given the existence of a servo motor in that situation.

The force exerted on the wheel can therefore be calculated as follows:

Is Known		Working Style
One slider with the load	$= \frac{640}{2} = 320\ kg$	$W = m.g$ $= (80)\ x\ (9.8) = 784\ N$
One wheel with a load	$= \frac{320}{4} = 80\ kg$	
Gravitational acceleration (g)	$9.8\ m/s^2$	

Materials and Material Combinations		Surface Conditions	Frictional Coefficient Static (μ_s)	Frictional Coefficient Kinetic (μ_k) (sliding)
Polytetrafluoroethylene (PTFE) (Teflon)	Steel	Clean and Dry	0.05 – 0.2	-

Is Known		Friction Occurs
Acting Force (N)	$784\ N$	$F_g = \mu\ N$ $= (0.125)(784)$ $= 98\ N$
Friction coefficient (μ) PTFE's material and Steel's material (0.05 – 0.2)	$0.125\ N$	

Figure 12: Teflon Material's Frictional Coefficient with Iron.

On the basis of Figure 12 above, it is presumed that the Y-axis slider travels to the right as a result of the motor's force. The friction force between the Y-axis pillar and the U-Wheel is thus seen as follows:

According to the calculations above, the motor must exert a force that is more than 98 N. Because the Y axis slider won't move if the motor's force is less than 98 N. If condition of The U-Wheel under normal force, It is presumed that the load is split across the two sliders because there are two sliders on the Y axis. It is expected that the load is distributed equally among the four U-shaped wheels on one slider, which operate on the pillars.

4 CONCLUSIONS

In general, the following can be said about this paper's overall contents:

The 20° helix angle on the tooth profile of the Helical Rack & Pinion Gear transmission element increases the amount of contact between the teeth during operation.

The Helical Rack & Pinion Gear transmission element's operating concept is to convert the circular rotation of the pinion into linear motion on the rack with a 20° helix angle.

Observing the transmission elements that may be utilized on the Y-axis slider is the first step in the planning and choosing of transmission elements. The criteria in the list of requirements for the Y-axis slider transmission elements are then used to evaluate and choose alternative transmission elements. The strength of the Helical Rack & Pinion Gear transmission element is then determined based on the received load, the active force, and the mounting position.

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