Saimaa University of Applied Sciences
Faculty of Technology, Lappeenranta
Mechanical Engineering and Production Technology

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Screw Conveyor Final report

Report 2018

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1 Introduction

The goal of the project was to make a full mechanical design of a product. The selected product had to fulfill the given criteria. The major criterion was that the mechanism had to have a rotating mechanism. Other criteria were, use of some standard components, use of some custom designed parts, etc. The recommended product for the group was a screw conveyor. The group had to decide the application area of the screw conveyor when designing it.

The product that was finalized was a screw conveyor for agricultural application. The usual conveying materials in the agricultural applications are paddy, wheat, sorghum, millet etc. The target set was to design a screw conveyor of conveying capacity of 5 tons/hour at a maximum recommended inclination of 33°.

A screw conveyor consists of a circular or U-shaped tube with a spiral blade that rotates. The major two types of screw conveyor are: shaftless screw conveyor and shafted screw conveyor. Shafted screw conveyor has a shaft along the length running through the spiral blade. Material is pushed along the bottom of the tube by the helix; thus, the tube does not fill completely. Screw conveyors are widely used for transporting and/or elevating particulates at controlled and steady rates. They are used in many bulk materials handling applications ranging from agriculture (i.e. conveying grain from storage bins to transport vehicles, mixing grain in storage, and moving grain in a bin to a central unloading point), to chemicals, pigments, and food processing etc.

2 Project planning

The project was completed by two members. Equal amount of work was divided between the members. However, most of the tasks was done by collaboration of both the members. The table 1 shows the responsibility that was divided among the group members.

Name	Responsibility
Arjun Paudel	1. Report preparation 2. Project scheduling & cost estimation 3. Progress scrutinizing 4. Technical parameter calculation 5. 3D-modeling & assembling 6. BOM & 2D-drawings
He Junjie	1. Report preparation 2. Project scheduling 3. Idea generation 4. 3D-modeling & assembling 5. BOM & 2D-drawings 6. Detail engineering work

Table 1 Member's responsibility

2.1 Scheduling

After the preliminary planning of the task, a project was planned in MS-project software. The tasks were more specifically defined in this planning. The time duration of the project was little more than 3 months, with starting date 06.09.2018. A screen shot of the project's schedule as planned in the start of the project is shown in figure 1.

	Task Mode	Task Name	Duration	Start	Finish	Pr	Resource Names
1		**Project Definition and planning**	**4 days**	**Thu 6.9.18**	**Tue 11.9.18**		**Junjie He;Arjun Paudel**
2		Topic Research and Introduction	1 day	Thu 6.9.18	Thu 6.9.18		Arjun Paudel;Junjie He
3		Project Scheduling	1 day	Fri 7.9.18	Fri 7.9.18	2	Arjun Paudel
4		Budget Planning and Risk analysis	2 days	Mon 10.9.18	Tue 11.9.18	3	Junjie He
5		**Product development**	**55 days**	**Wed 12.9.18**	**Tue 27.11.18**	**1**	**Junjie He;Arjun Paudel**
6		Brainstorming	5 days	Wed 12.9.18	Tue 18.9.18		Arjun Paudel;Junjie He
7		Conceptual design	5 days	Wed 19.9.18	Tue 25.9.18	6	Arjun Paudel
8		Engineering specification	5 days	Wed 26.9.18	Tue 2.10.18	7	Junjie He
9		Product design and development	40 days	Wed 3.10.18	Tue 27.11.18	8	Arjun Paudel;Junjie He
10		**Project Wrap up**	**8 days**	**Wed 28.11.1**	**Fri 7.12.18**	**5**	**Junjie He;Arjun Paudel**
11		Presentation Planning	2 days	Wed 28.11.1	Thu 29.11.18		Arjun Paudel;Junjie He
12		Presentation execution	1 day	Fri 30.11.18	Fri 30.11.18	11	Arjun Paudel;Junjie He
13		Final Report	5 days	Mon 3.12.18	Fri 7.12.18	12	Arjun Paudel;Junjie He

Figure 1 Project's schedule

2.2 Engineering specification

The table 2 shows the list of engineering specifications created for the project. The last column of the table shows the updated parameters during the development of the project.

Demand/Wish	Importance (1-5)	Parameters	Updates
		Geometry	
D	5	Overall Length < 3000 mm	3050 mm
D	5	Housing diameter < 500 mm	350 mm
D	5	Overall Height < 3000 mm	1633
W	3	Screw diameter < 500 mm	300 mm
W	3	Shaft length :3000 mm	3000 mm
W	3	Shaft diameter < 100mm	80 mm
W	2	Dry Mass< 250 kg	227 kg
W	3	Screw pitch: 300mm	300 mm
		Engine	
D	5	Type: electric motor	✓
W	5	Power < 5 kw	1.1 KW
W	5	Speed < 50 RPM	34 RPM
W	5	Torque > 100 Nm	305 Nm
		Capacity	
D	5	Conveying capacity: 5 tons/hour	5.5 tons/hr
		Safety	

D	5	Meet all the laws and regulations	✓
		Manufacturing	
		Method: Cut and folded flights	
D	5	Material of the shaft: Aluminium or Steel	S355
D	3	Material of the housing shell: Steel or aluminium	S355
D	4	Material of the screw blade: surface harden steel	S355
		Costs	
W	5	Target price < 5000€	
		Deadlines	
D	5	Concept finalize: 10.10.2018	✓
D	5	Required components selection: 12.11.2018	✓
D	5	Project completion: 10.12.2018	✓

Table 2 List of engineering specifications

3 Component Selection and calculations

3.1 Conveyor capacity calculation

The targeted transfer capacity for our conveyor is 5 tons per hour or 5000 kg/hr. This value is based on the average production of harvesting land.

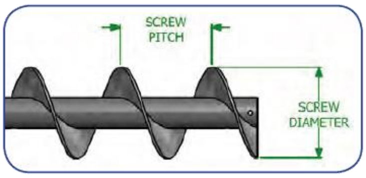


Figure 2 screw conveyor parts and name

Length of the conveyor: 3000mm

Screw Diameter: 300 mm

Screw Pitch: 300 mm

Density of the transfer material: 45 lb/ft^3 = 720 kg/m^3 [1]

Capacity factor (CF) for standard pitch: 1 [2]

Capacity factor (CF) for cut and folded flights: 2.54 [2]

Trough loading factor: 0.45 [2]

Required capacity = $\frac{5000\ \mathrm{kg/hr}}{720\ \mathrm{kg/m3}}$ = 6.944 m^3/hr = 245 ft^3/hr

Selection capacity (SC) = required capacity X capacity factor = 245 X 1 X 2.54 = 600 ft^3/hr

This selection capacity will be used to select proper screw conveyer diameter and speed from the capacity table. The recommended trough loading factor for agricultural products is 0.45. From the table 2 a 12-inch (300 mm equivalent) conveyor will convey 2,813 ft^3 = 80m^3 per hour at the maximum recommended speed of 145 RPM. The actual speed conveyor speed is calculated by dividing the selection capacity by capacity at 1 RPM i.e. 600/19.4 = 31 RPM

In conclusion the correct speed for a 300 mm diameter screw conveyor with cut and folded flights and standard pitch is 31 RPM for conveying 6.944 m^3/hr.

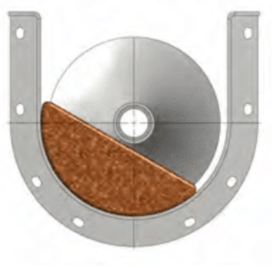
Trough Loading	Screw Dia. (in.)	Max. RPM *	Capacity in ft^3/hr	
			At Max. RPM	At 1 RPM
 45%	4	190	116	0.61
	6	165	368	2.2
	9	155	1,271	8.2
	12	145	2,813	19.4
	14	140	4,368	31.2
	16	130	6,071	46.7
	18	120	8,112	67.6
	20	110	10,307	93.7
	24	100	16,400	164.0
	30	90	28,800	320.0
	36	75	41,490	553.2

Figure 3 Capacity table

3.2 Engine Selection

The engine of the screw conveyor is a motor. In order to make an appropriate section of a motor, power required for the application was calculated. A motor with slightly higher rating than the calculated power was selected from a manufacturer's site.

Motor Power calculation

The factors accounted for the power calculation are

Q_m = feed rate (tons/hr) = 2.452 tons/hr

f_L = length factor = 1.875

f_V = feeding material factor = 2

f_s = feeding inlet factor = $1 + \frac{4 \text{ x } D \text{x } H}{\pi(D^2 - d^2)} = 1 + \frac{4 \text{ x } 0.350 \text{ x } 0.150}{\pi(.350^2 - 0.340^2)}$ =10.69

L = distance between the inlet and outlet of the conveyor (m) = 3 m

H = vertical distance of inlet and outlet (m) = 1 m

The required power can be calculated from following formula:

$P_K = \frac{Qm \text{ x } f \text{ x } (L+H)}{360}$

Where f = f_L x f_V x f_S = 1.875 x 2 x 10.69 = 40.07

So, $P_K = \frac{2.452 \text{ x } 40.07 \text{ x } (3+0.150)}{360}$ = 0.859 kW

The motor power can now be calculated as:

$P_m = k_a$ x P_k where k_a is run time factor and k_a = 1.25

Therefore P_m = 1.25 x 0.859 = 1.07 kW

Therefore, for the screw conveyor designed, motor with power of 1 kW will be selected.

A parallel shaft helical gear motor was selected from website of SEW Eurodrive company.

The technical data of the selected motor are:

Motor power	1.1 kW
Rated motor speed	1445 RPM
Output speed	34 RPM
Overall gear ration	42.86
Output torque	305 Nm
Hollow shaft	35 mm

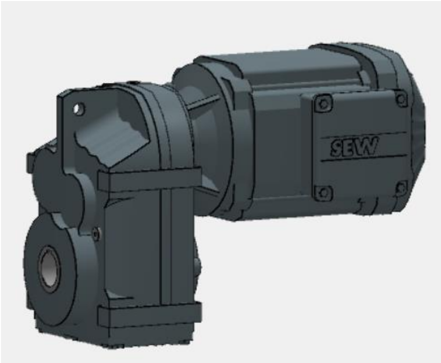


Figure 4 Preview of selected motor

Motor voltage	230
Net weight	37 Kg

3.3 Bearing lifetime calculation

The shaft was designed to be of 50 mm diameter where bearing should to be mounted. Therefore, a bearing with bore 50 mm had to be selected. The figure 1 shows the calculation of equivalent load acting on the bearing which was calculated to be 4423 N. The table for rated capacities of bearing in figure 4 shows that a L00XLt 50 mm bore diameter bearing has a rated capacity of 6.10 KN. So, this would be an appropriate bearing for the design as it can handle the loading that is acting on the system.

Bearing Life time calculation

Thrust Load on the bearing

$$F_t = \frac{M_v}{R_m \cdot \tan(\alpha+\rho)}$$

Where, M_v = Torque = 305 Nm

$R_m = \frac{0{,}7D}{2} = \frac{0{,}7 \cdot 0{,}35}{2} = 0{,}175$

α = inclination of Screw Conveyor = 33°

$\rho = \tan^{-1}(\mu)$; μ = frictional Coeff. = 0,3 ; ∴ $\rho = \tan^{-1}(0{,}3) = 17°$

$$\therefore\ F_t = \frac{305}{0{,}175 \cdot \tan(33°+17°)} = 1462{,}4\ N$$

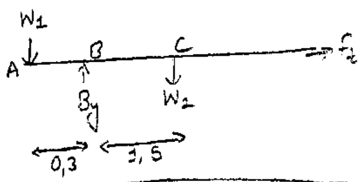
Force distribution along the shaft

W_1 = motor weight = 37·9,8 = 363 N

W_2 = Weight of Conveyor with loading

= (139+275)·9,8 = 4060 N

& F_t = 1462,4 N



$\boxed{\text{free body diagram}}$

$$+\uparrow \Sigma F_y = 0 \Rightarrow B_y - W_1 - W_2 = 0$$

$$\Rightarrow B_y = 363 + 4060 = 4423\ N$$

∴ Radial loading (f_r) = 4423 N

$\frac{f_t}{f_r} = \frac{1462{,}4}{4423} = 0{,}33 < 0{,}35$ So, equivalent load $(F_e) = F_r = 4423$ N

Figure 5 Bearing equivalent load calculation

TABLE 14.2 Bearing Rated Capacities, C, for 90×10^6 Revolution Life with 90 Percent Reliability

	Radial Ball, $\alpha = 0°$			Angular Ball, $\alpha = 25°$			Roller		
Bore (mm)	L00 Xlt (kN)	200 lt (kN)	300 med (kN)	L00 Xlt (kN)	200 lt (kN)	300 med (kN)	1000 Xlt (kN)	1200 lt (kN)	1300 med (kN)
10	1.02	1.42	1.90	1.02	1.10	1.88			
12	1.12	1.42	2.46	1.10	1.54	2.05			
15	1.22	1.56	3.05	1.28	1.66	2.85			
17	1.32	2.70	3.75	1.36	2.20	3.55	2.12	3.80	4.90
20	2.25	3.35	5.30	2.20	3.05	5.80	3.30	4.40	6.20
25	2.45	3.65	5.90	2.65	3.25	7.20	3.70	5.50	8.50
30	3.35	5.40	8.80	3.60	6.00	8.80	2.40[a]	8.30	10.0
35	4.20	8.50	10.6	4.75	8.20	11.0	3.10[a]	9.30	13.1
40	4.50	9.40	12.6	4.95	9.90	13.2	7.20	11.1	16.5
45	5.80	9.10	14.8	6.30	10.4	16.4	7.40	12.2	20.9
50	6.10	9.70	15.8	6.60	11.0	19.2	5.10[a]	12.5	24.5
55	8.20	12.0	18.0	9.00	13.6	21.5	11.3	14.9	27.1
60	8.70	13.6	20.0	9.70	16.4	24.0	12.0	18.9	32.5
65	9.10	16.0	22.0	10.2	19.2	26.5	12.2	21.1	38.3
70	11.6	17.0	24.5	13.4	19.2	29.5		23.6	44.0
75	12.2	17.0	25.5	13.8	20.0	32.5		23.6	45.4
80	14.2	18.4	28.0	16.6	22.5	35.5	17.3	26.2	51.6
85	15.0	22.5	30.0	17.2	26.5	38.5	18.0	30.7	55.2
90	17.2	25.0	32.5	20.0	28.0	41.5		37.4	65.8
95	18.0	27.5	38.0	21.0	31.0	45.5		44.0	65.8
100	18.0	30.5	40.5	21.5	34.5		20.9	48.0	72.9
105	21.0	32.0	43.5	24.5	37.5			49.8	84.5
110	23.5	35.0	46.0	27.5	41.0	55.0	29.4	54.3	85.4
120	24.5	37.5		28.5	44.5			61.4	100.1
130	29.5	41.0		33.5	48.0	71.0	48.9	69.4	120.1
140	30.5	47.5		35.0	56.0			77.4	131.2
150	34.5			39.0	62.0		58.7	83.6	
160								113.4	
180	47.0			54.0			97.9	140.1	
200								162.4	
220								211.3	
240								258.0	

[a]1000 (Xlt) series bearings are not available in these sizes. Capacities shown are for the 1900 (XXlt) series.

Source: New Departure–Hyatt Bearing Division, General Motors Corporation.

Figure 6 Bearing rated capacities

Bearing Life time Calculation

$$L = K_r \cdot L_R \left(\frac{C}{F_e \; K_a}\right)^{3,33}$$

Where

K_r = reliability factor = 0,45 (90% reliability)

L_R = Life corresponding to rated capacity
$= 90 \times 10^6$ revolutions

C = rated capacity = 6,10 KN = 6100 N

K_a = Application factor = 1,5 (for light impact usages)

$$\therefore \; L = 0{,}45 \cdot 90 \cdot 10^6 \left(\frac{6100}{4423 \cdot 1{,}5}\right)^{3,33} = 30{,}61 \times 10^6 \text{ rev}$$

output speed of motor = 34 rpm

$$\therefore \; \text{Life time} = \frac{30{,}61 \times 10^6}{34} = 0{,}9 \times 10^6 \text{ minutes}$$
$$= 15009 \text{ hours}$$

for a average use of 10 hours a day; bearing lifetime $= \frac{15009}{(365 \times 10)}$
$= 4{,}1$ years.

Figure 7 Bearing Life time calculation

3.4 Deformation calculation

In this chapter, individual deformation in screw conveyor and in the housing of the screw conveyor is calculated. The deformation calculated is the maximum deformation both the part can possibly have. During the deformation calculation, the force caused by the loading of the grains (conveying materials) is accounted in both cases (screw shaft and the housing) as both the conveyor and the shaft will be supporting the loading.

The calculations performed are as follow:

Weight of the motor $= 37 \times 9{,}8 \simeq 363\ N \quad (W_1)$

mass of Conveyor with housing $= 128 + 62 = 190\ kg$

mass of loading during Conveying grains $= \rho \cdot V$

$$= \rho \cdot \pi r^2 h$$

$$= \rho \cdot 45\%\ \text{of}\ \pi \cdot 0{,}3^2 \times 3$$

$$= 720 \times 0{,}45 \times \pi \times 0{,}3^2 \times 3$$

$$= 274{,}8\ kg$$

$$\simeq 275\ kg$$

Weight of Conveyor (total weight) $= (190 + 275)\, 9{,}8$

$$\simeq 4555\ N \quad (W_2)$$

Figure 8: Force calculation

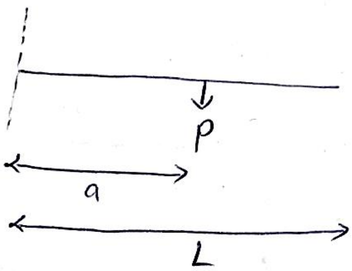
deformation of outer shell

Loading on the shell = Own weight + grains

$= 128 + 275 = 403\ kg$

Force (P) $= 403 \times 9{,}8 = 4000\ N$

Free body diagram



$a = 1{,}5\,m$

$L = 3\,m$

$P = 4000\,N$

E (young's modulus) $= 2{,}05 \times 10^{11}\ N/m^2$

Moment of Inertia (I) $= \frac{\pi}{64}(d_2^4 - d_1^4)$

$= \frac{\pi}{64}(0{,}350^4 - 0{,}340^4)$

$= 80{,}64 \times 10^{-6}\ m^4$

deformation of outer shell is given by following formula:

$$\delta_B = \frac{Pa^2}{6EI}(3L - a)$$

$$= \frac{4000 \times 1{,}5^2}{6 \times 2{,}05 \times 10^{11} \times 80{,}64 \times 10^{-6}}(3 \times 3 - 1{,}5)$$

$$= 0{,}00068\ m$$

$$\simeq 0{,}68\ mm$$

$\therefore$ Maximum deformation in the shell is 0,68 mm.

Figure 9: Deformation calculation of outer shell (housing)

deformation of Screw Shaft

Loading on the screw shaft $= \overset{139}{\cancel{62}} + 275$

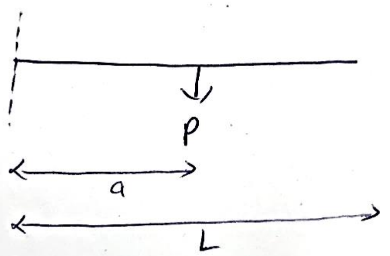
$= \cancel{337}$ kg

$= 414$ kg

Force (P) $= 337 \times 9{,}8 \simeq \cancel{3303\ N}$

$\simeq 4060$ N

Free body diagram



$a = 1{,}5$
$L = 3$
$P = 3303$

Young's modulus $(E) = 2{,}05 \times 10^{11}$ N/m^2

Moment of inertia $(I) = \frac{\pi}{64}\, 0{,}08^4 = 2{,}01 \times 10^{-6}$ m^4

deformation of the Screw (shaft) is given by following formula:

$$\delta_B = \frac{Pa^2}{6EI}(3L - a)$$

$$= \frac{4060 \times 1{,}5^2\,(3 \times 3 - 1{,}5)}{6 \times 2{,}05 \times 10^{11} \times 2{,}01 \times 10^{-6}}$$

$$= 0{,}0277 \text{ m}$$

$$\simeq 27 \text{ mm}$$

∴ The maximum deformation in the Screw Conveyor Shaft will be 27mm

Figure 10: Deformation calculation of screw shaft

4 Results

The speed of selected motor was 34 RPM. The requirement speed was of 31 RPM. So, the system should have little more capacity than the target capacity of 5 tons/hour. The actual capacity of the conveyor can be calculated by retracing the calculation made on section “3.1 conveyor capacity calculation”. The calculations are shown as follow:

Motor speed = 34 RPM

Selection capacity = 19.4·34 = 660 ft^3/hr

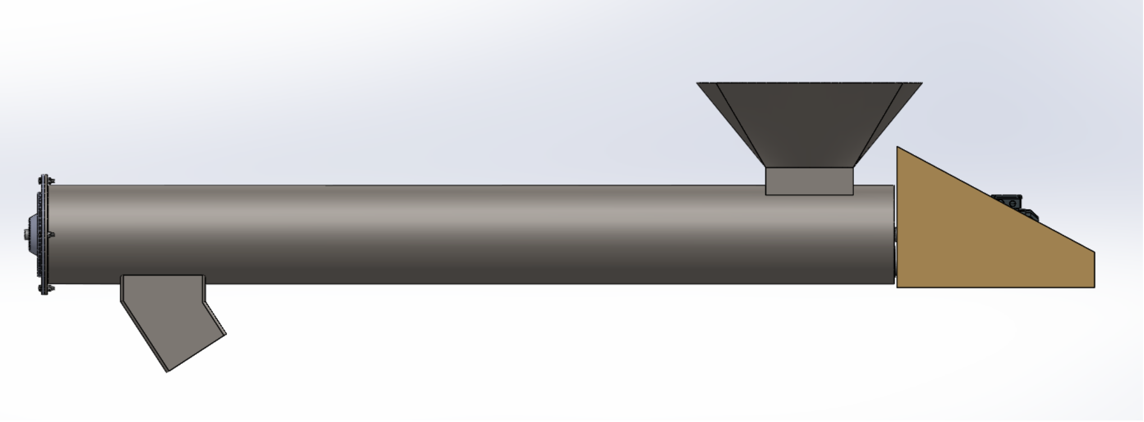
Required capacity = selection capacity/ capacity factor = 660/2.54 = 269.68 ft^3/hr

This require capacity is the actual conveying capacity. In SI unit the equivalent amount is 7.63 m^3/hr. Since density of transferring material was 720 kg/m^3. Therefore, the conveying capacity of the conveyor would be 5493 kg. Approximately 5.5 tons of the material can be transferred by the conveyor at the maximum recommended inclination of 33°.

5 CAD modelling

After the selection of suitable components required in the project, a complete CAD of the system was built in SolidWorks.

The following pictures shows the parts and assembly of the system.



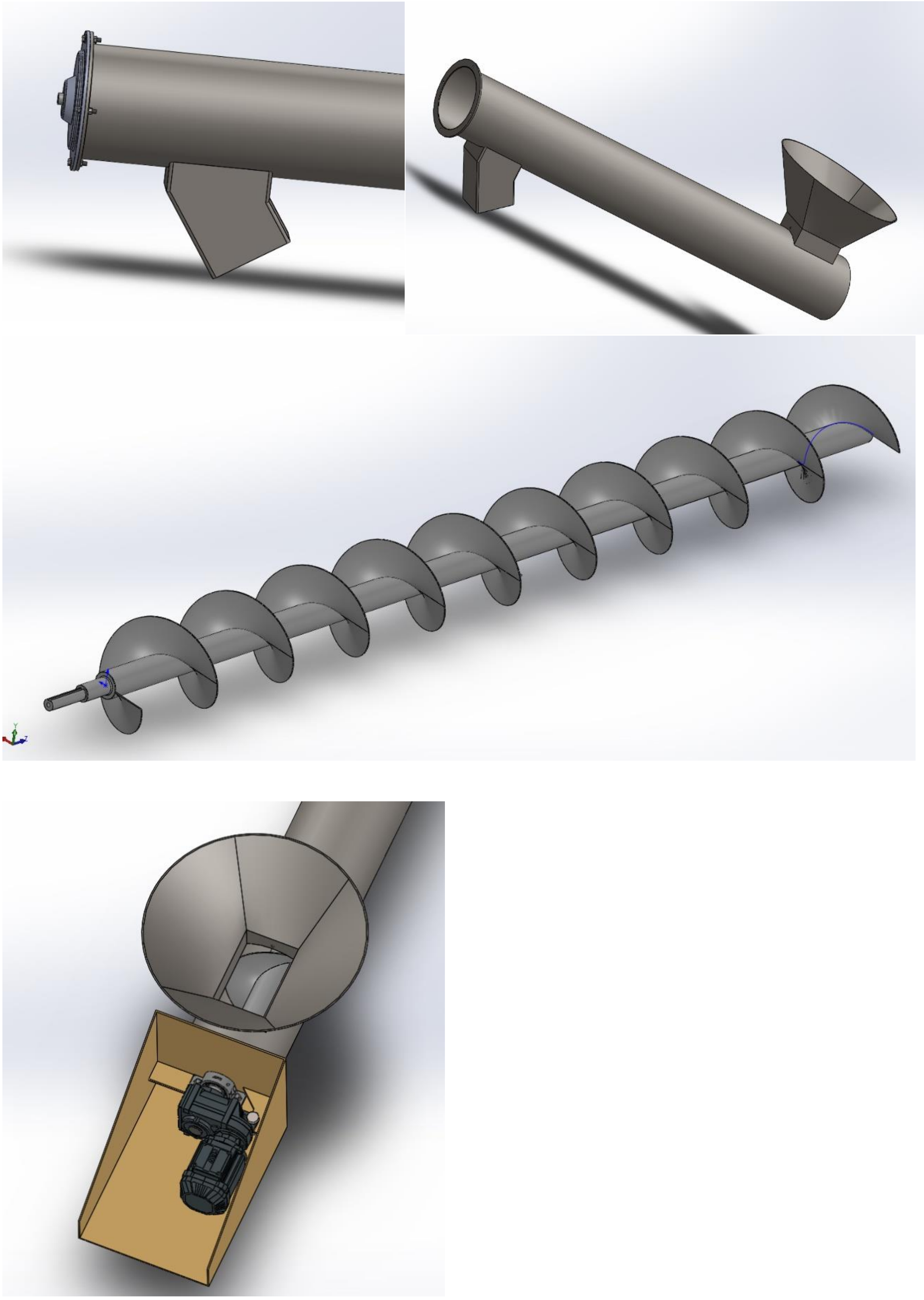


Figure 11: 3-D models of the system

6 2D drawings

All 2D drawings are attached at the end of the document.

7 Summary

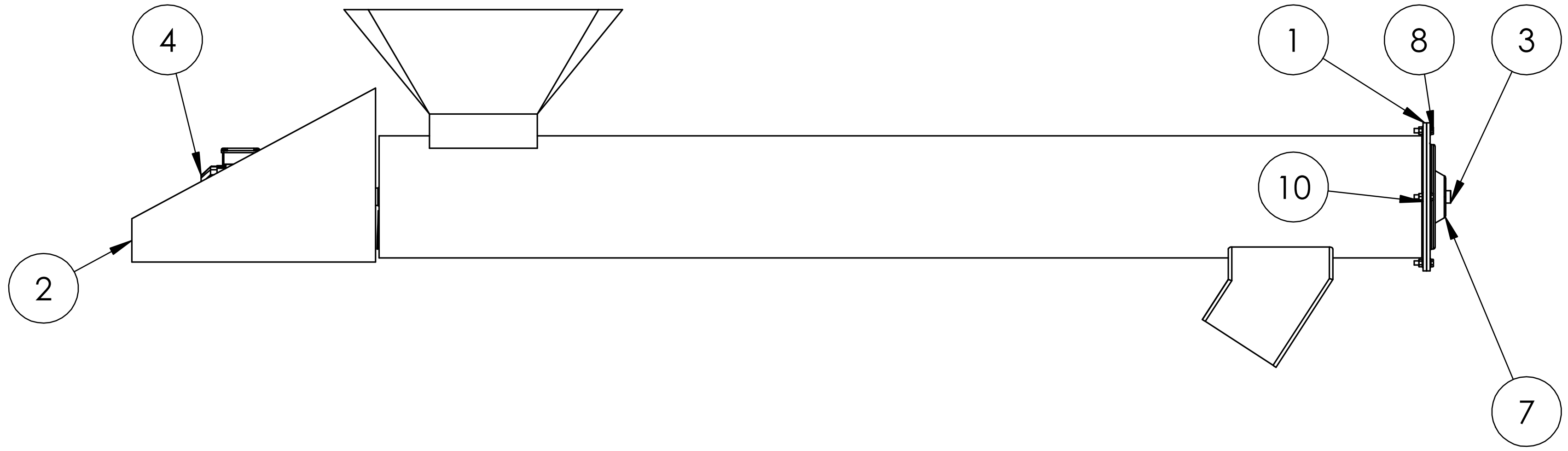
The project was completed on time. The set target of the project was to design a screw conveyor for agricultural application to elevate/transfer grains with a capacity of 5 tons/hr. The target of the project was achieved with the theoretical capacity of 5.5 tons/hr.

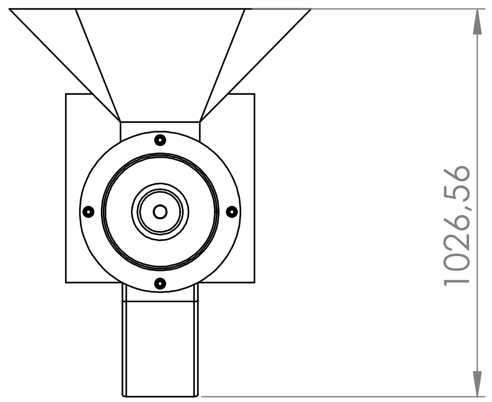
The major problems faced during the project were lack of knowledge of the product itself, inexperience with the project work execution methodology, and amateur in professional designing of the parts.

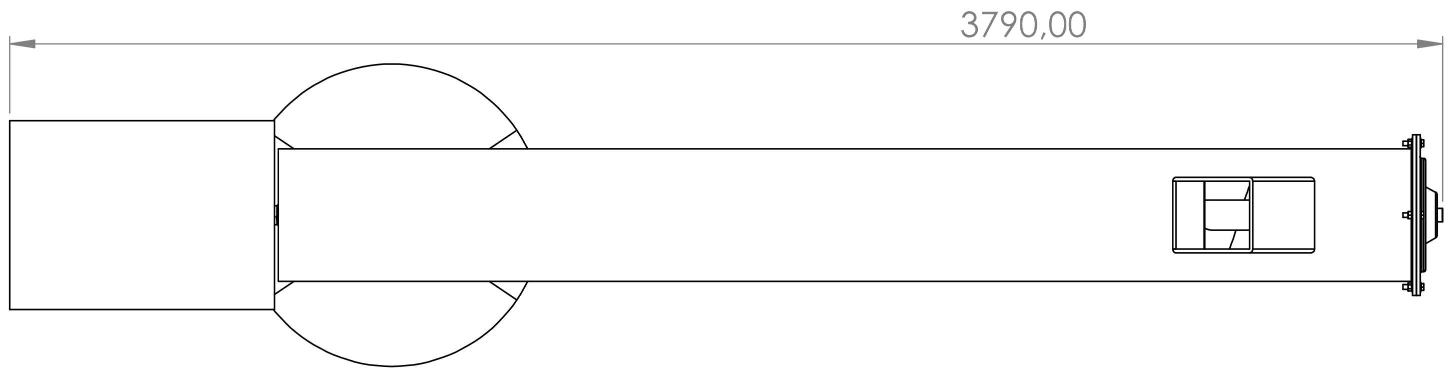
The major things that would be done differently in doing future similar projects are spending more time in doing through background study about the topic before jumping into designing. Make a proper plan from the background study about the execution of the task and finally when designing of components always try to make a standard component.

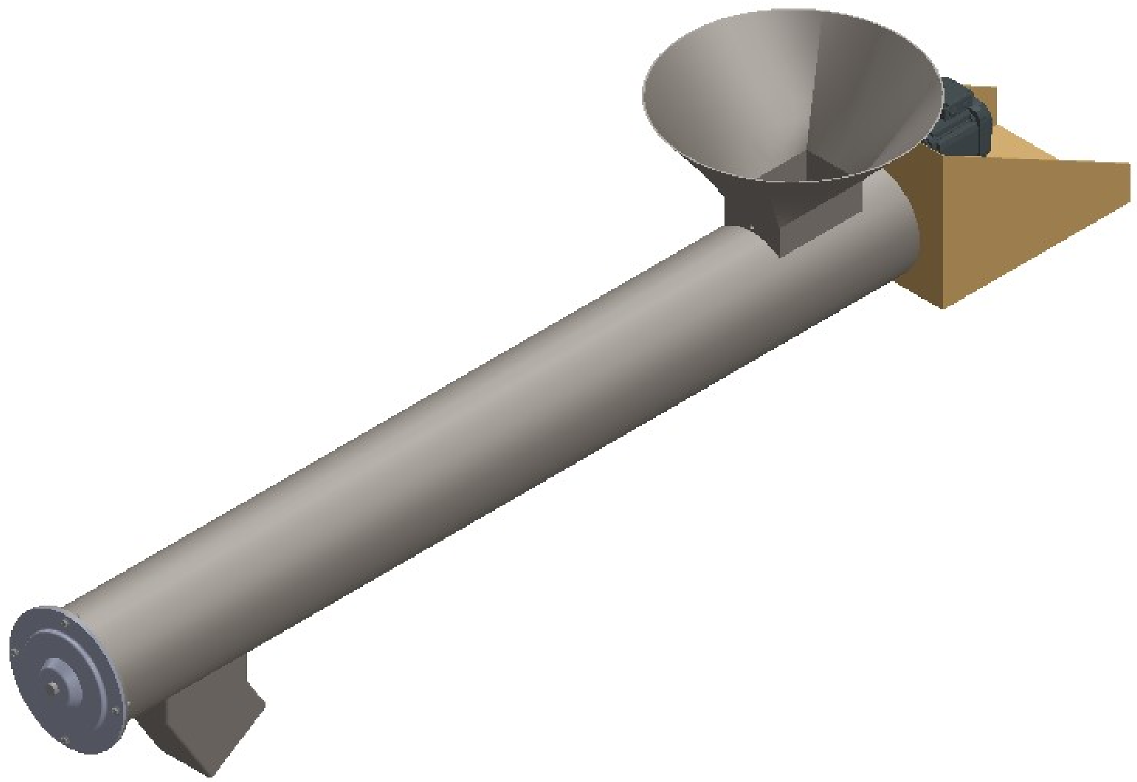
List of Tables

List of Figures









ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	shell		1
2	motor housing		1
3	new screw		1
4	gear motor	PART-SSBohrung 2_7-DESC	1
5	heavy hex screw_am		1
6	hex nut heavy_am		1
7	END PLATE		1
8	M12-1.75 x 45		4
9	M12-1.75 x 50		2
10	M12-1.75		4
11	key		1
12	SYJ 45 KFH		1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

WEIGHT:

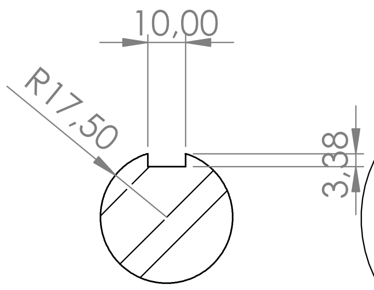
DWG NO.

Screw conveyor

A3

SCALE:1:50

SHEET 1 OF 1



SECTION A-A
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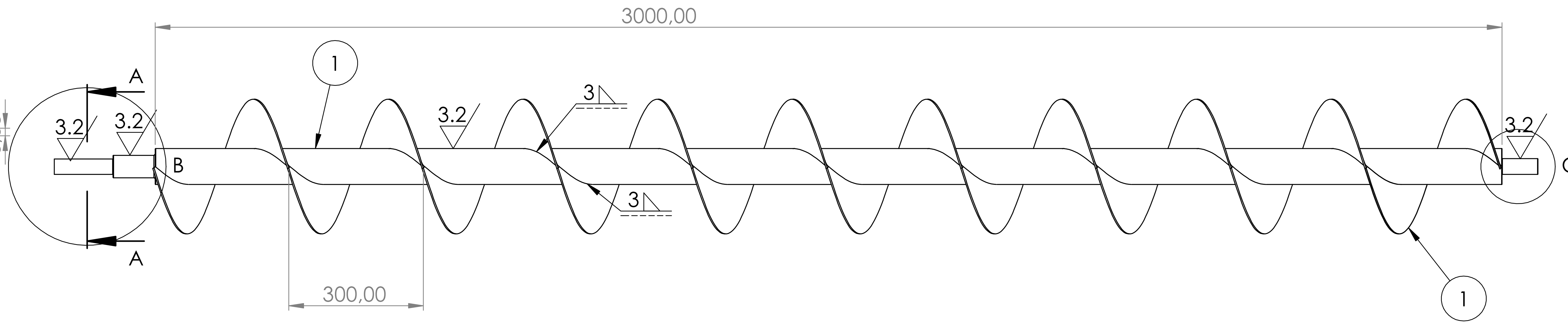

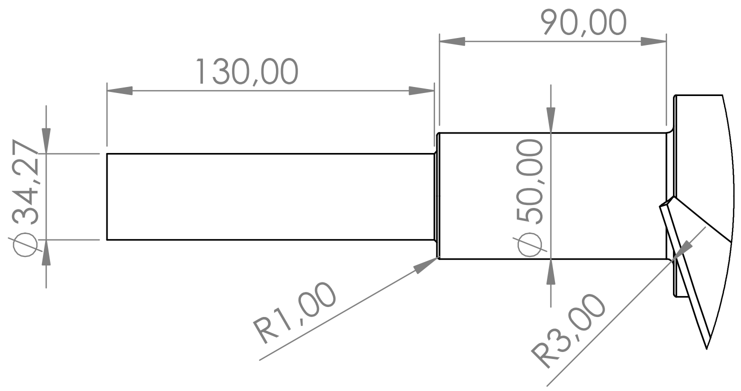

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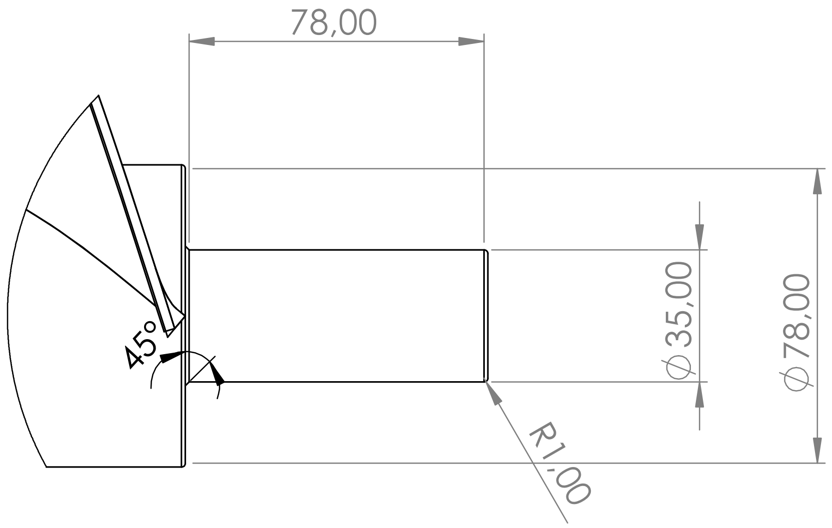
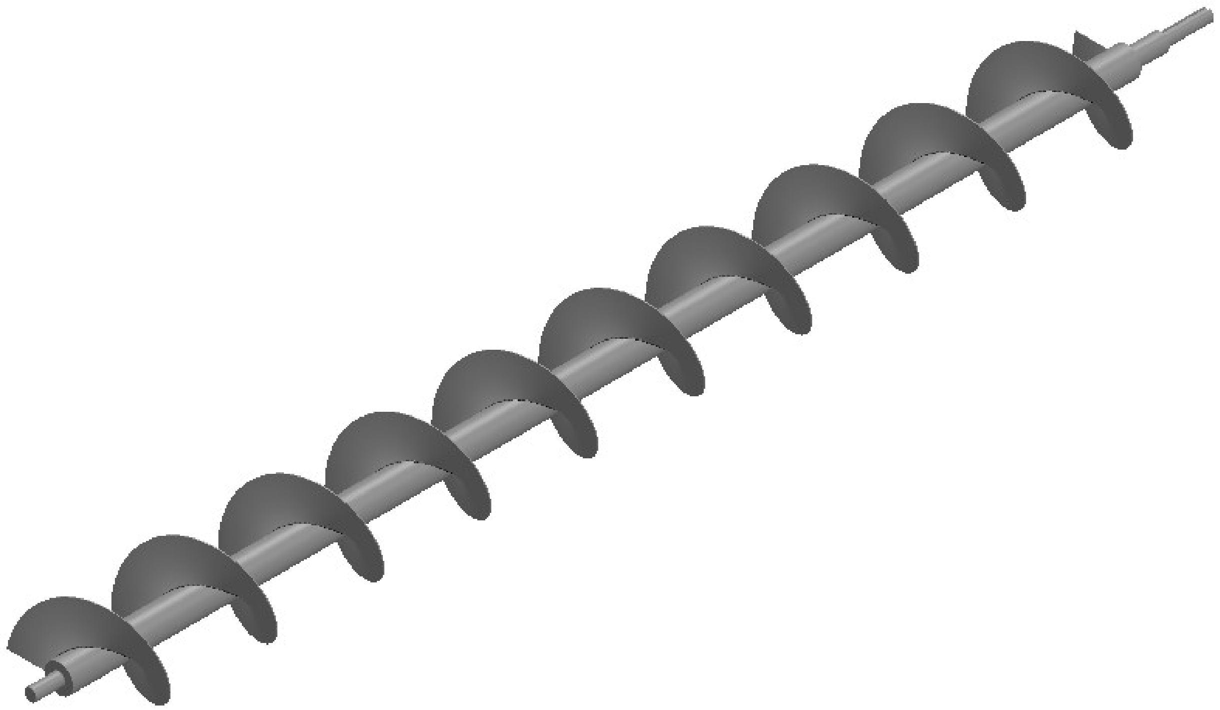


DETAIL C
SCALE 1 : 2



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Screw shaft	Material: S355	1
	Blade	S355 Flatten part welded to shaft	10
	Shaft	S355	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

DWG NO.

Screw shaft

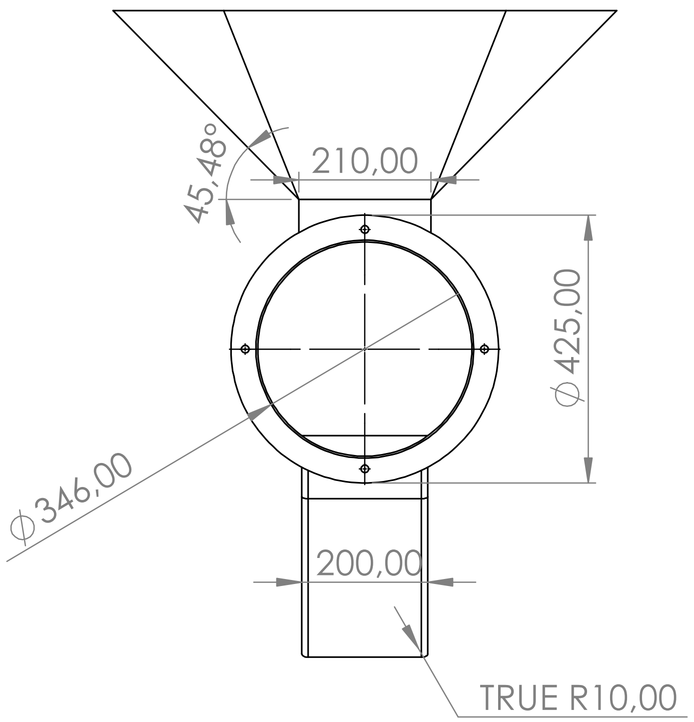
A3

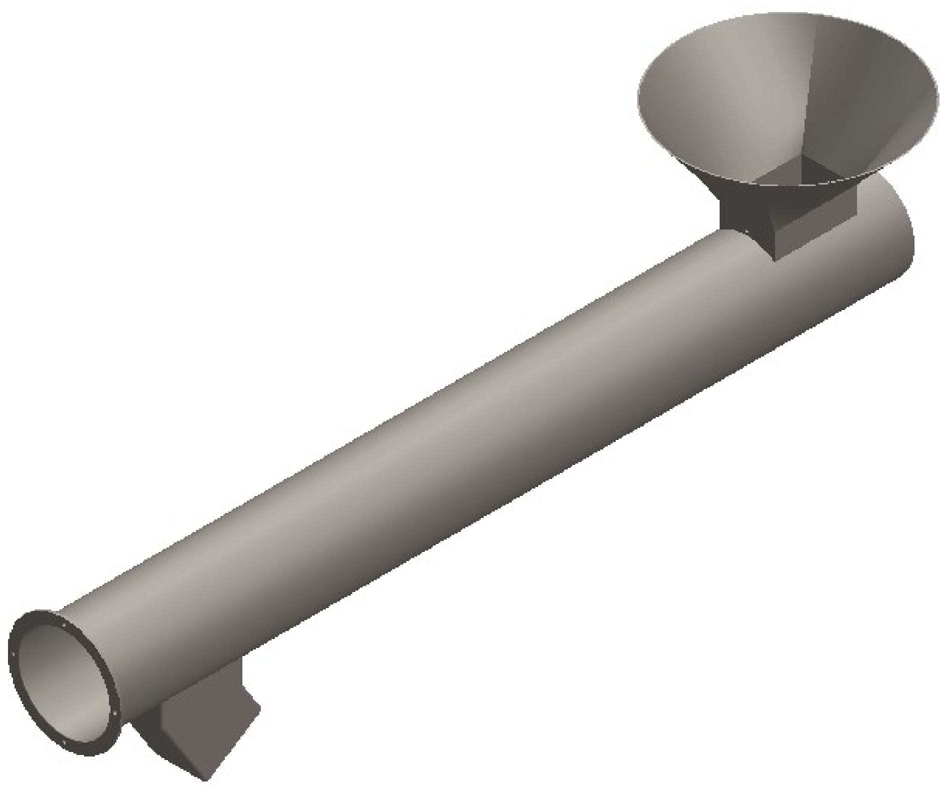
WEIGHT:

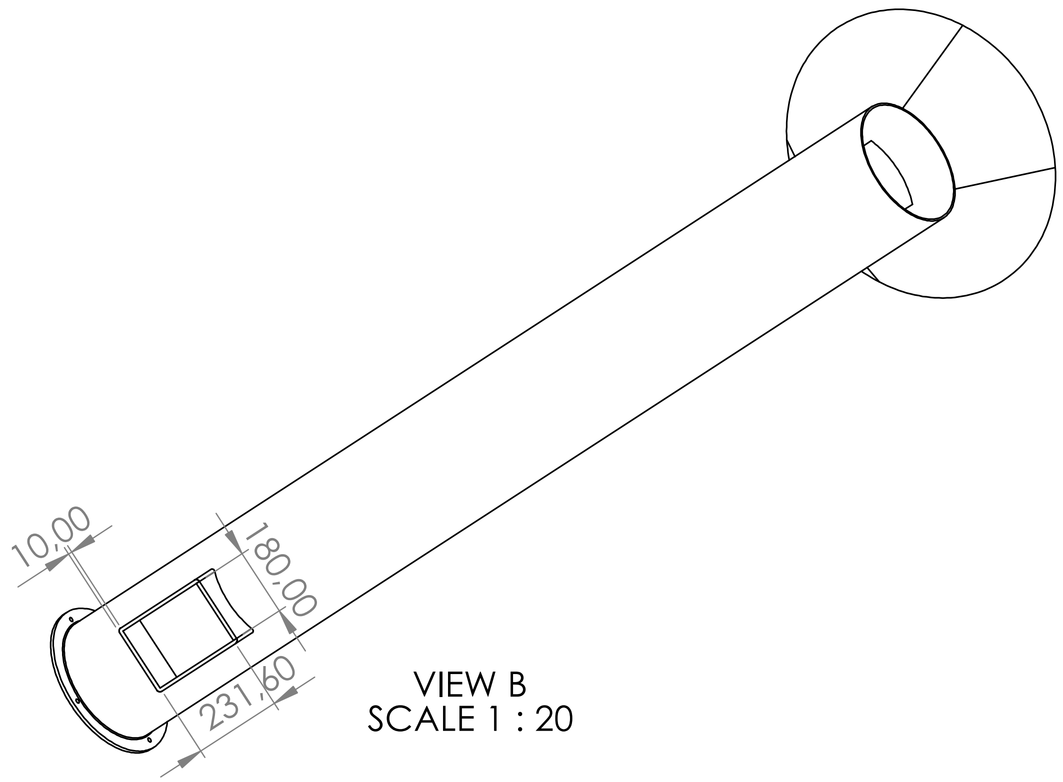
SCALE:1:50

SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	shell	Material: S355	1

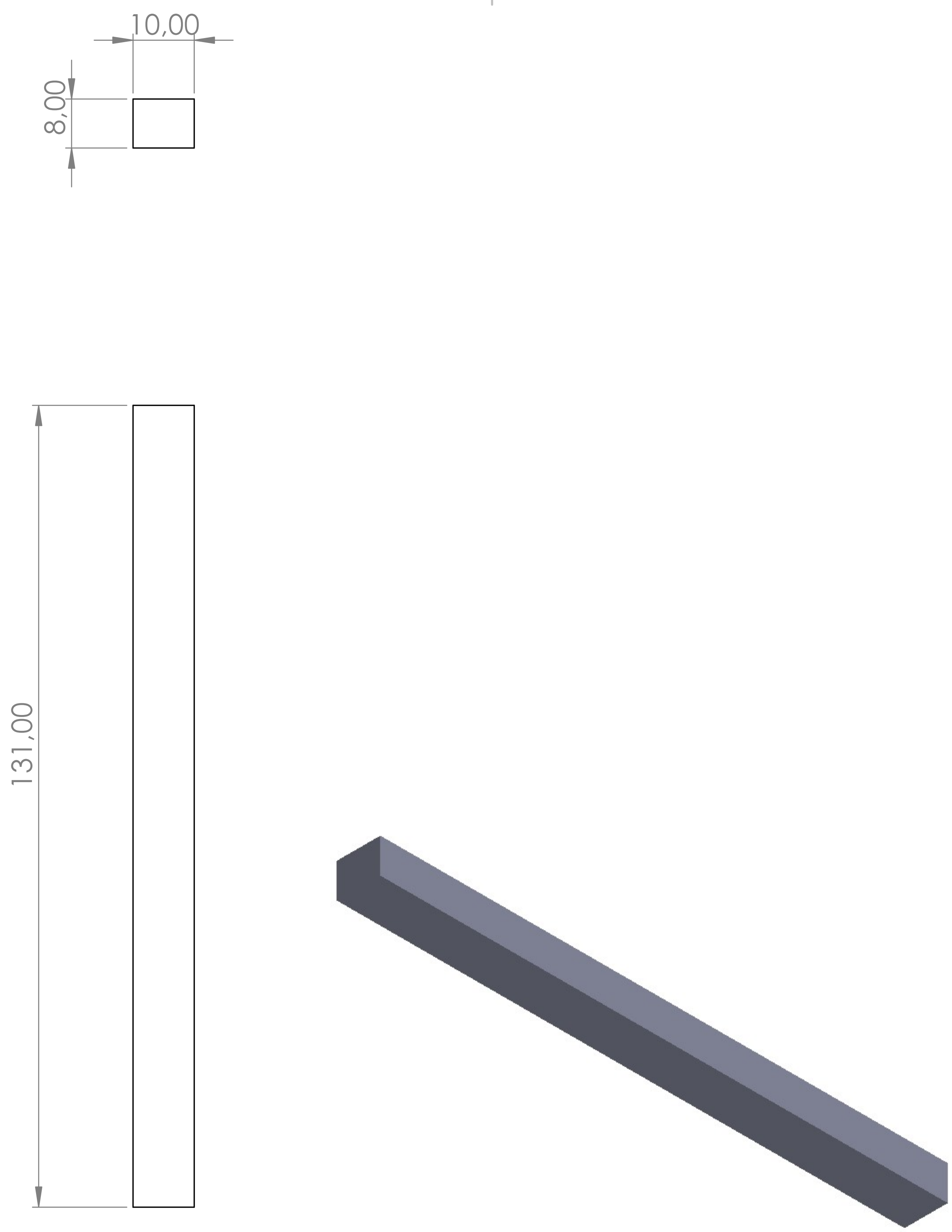






VIEW B
SCALE 1 : 20

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL:	DWG NO. shell	A3
			WEIGHT:	SCALE:1:50	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL: S355

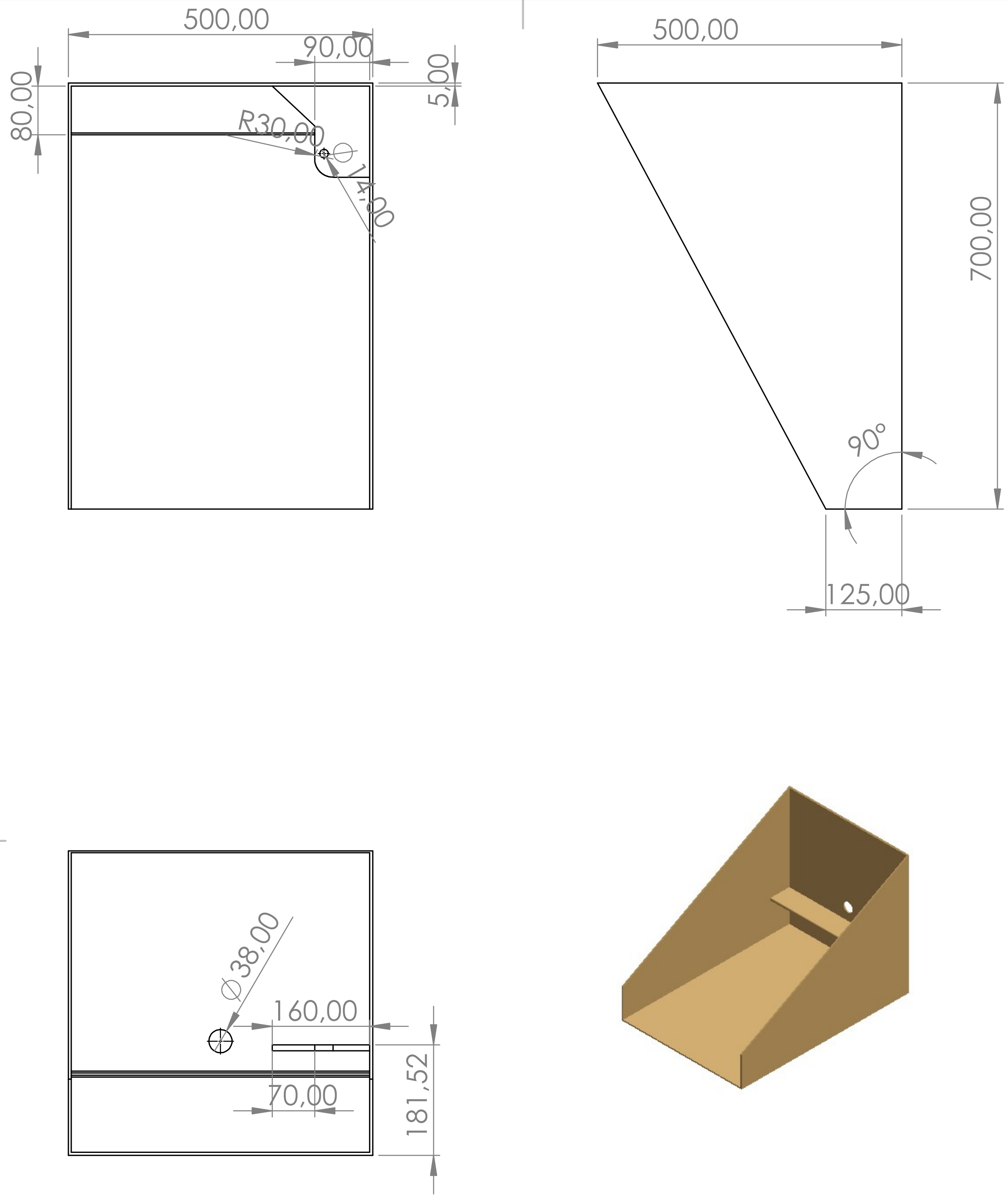
DWG NO. key

A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	motor housing	Material: S355	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

DWG NO.

motor housing

A4

WEIGHT:

SCALE:1:20

SHEET 1 OF 1