Technology and Equipment for Collecting Beach Cast Macroalgae

Developed by: Foundation “Attīstības fonds “Stari””

Project Customer: Kurzeme Planning Region

Liepaja, 2021

Report has been developed on request of Kurzeme planning region for the Interreg Baltic Sea Region Programme 2014-2020 financed project Nr. R097 „Growing Algae Sustainably in the Baltic Sea "(GRASS) supported by the European Regional Development Fund.

Report reflects authors` standpoint –managing authority of the Interreg Baltic Sea Region Programme 2014-2020 is not responsible for possible use of information included.

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Introduction

Emerging possibilities of macroalgae use, emphases need of efficient techniques and equipment for collecting macroalgae. Collecting beach cast macroalgae has its own specific problems, mainly sand contamination, and high moisture, as well as time constraints when it comes to collecting a significant amount of macroalgae.

To determine the most efficient solution for collecting algae in autumn 2020, on Liepaja beach, several front loader grate buckets were tested. The grate bucket was chosen as it was mentioned in research made in Trelleborg, Sweden as the most efficient tool [1].

New prototype of grate bucket was developed by eng. Jury Mazherikov, using SolidWorks software package, both, for detailed design and structural calculations. Detailed drawings were designed for fabrication of improved grate bucket details, as well as all assembly welding made.

When the prototype was ready, it was tested, and test results were compared with previous tests of different design grate bucket. Obtained results were better for the new prototype as it was anticipated. Economical comparison was made by oec. Arvils Jakabsons and results shoved supremacy of new version of grate bucket.

1. Selected techniques and equipment for studies

Collecting beach cast algae worldwide has very wide techniques and equipment used. Most common is use of agriculture and utility machinery, however France and Canada have designed special machines on basis of combine harvesters with high productivity and high quality of collected material.

Two main parameters are crucial for collected algae – moisture and contamination of sand. Specialized machinery has the best quality collected algae because the collection is done in near shallow water, close to the beach. So, there is minimum sand and moisture drained out quickly.

Using most widespread agricultural or utility machinery, it is impossible to collect algae in water. Using this type of machinery, the collection is located on beach. In this case most suitable machinery is the one with less sand content in collected algae. Grate buckets mounted on front loaders, exposed the best quality of collected material. Task of the study was to find optimal design of grate buckets for collecting beach cast macroalgae. Straw press CLAAS 62 was also tested, to check its performance in compacting algae by roll press.

2. Comparable tests and results for grate buckets

Experience shows that the most efficient instrument for collecting macroalgae, mostly *Furcellaria lumbricalis* algae from beach cast deposits are grate buckets. Mounted on front loaders, these tools have two most important features – dewatering capability and limited sand contamination. Those features are important if algae are planned for further processing.

Grate buckets are designed in several shapes and our task was to test these different types and find the most fitting to the task of beech collecting algae.

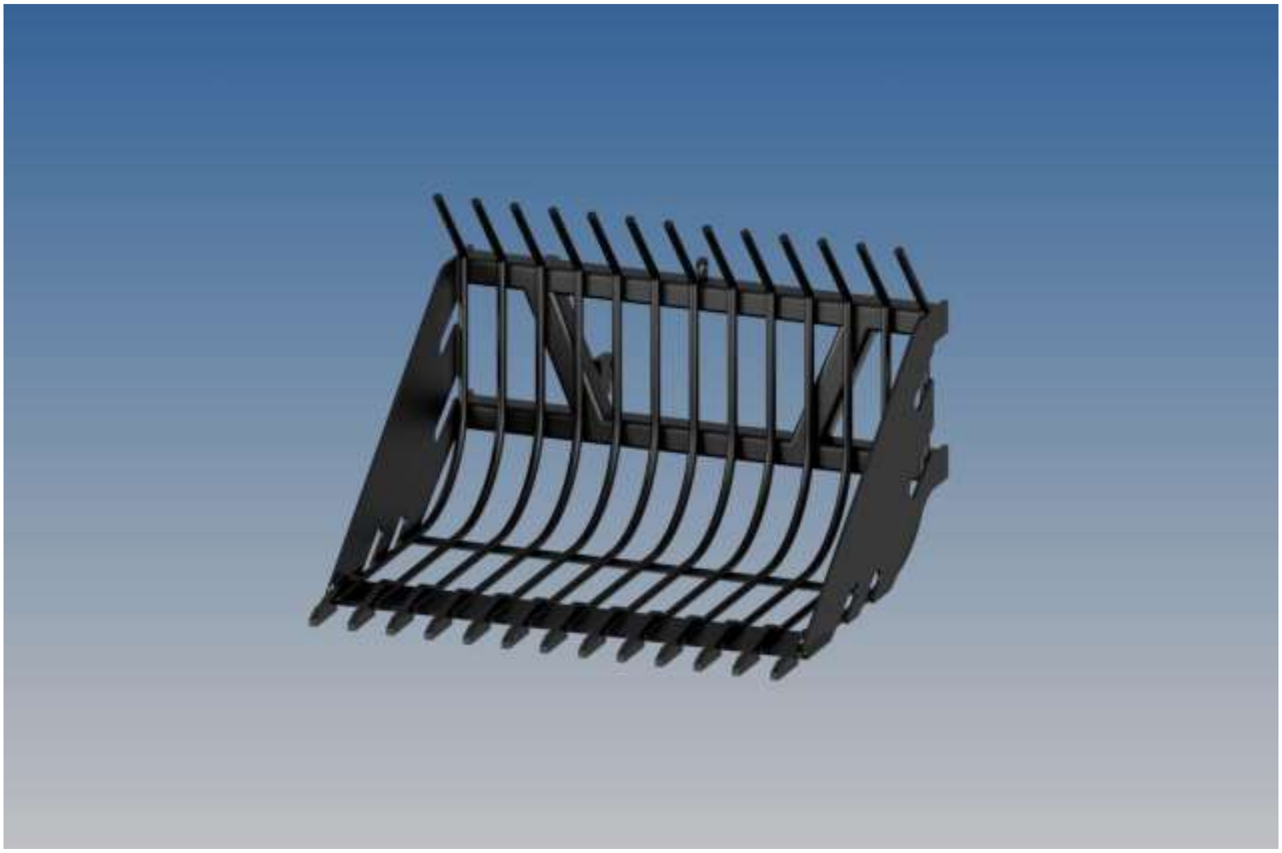
The first example (further in text - basic bucket) for tests we had MTM type stone bucket (https://www.voka.lv/), 1,5 m wide, 18 bar with distance of 90 mm, made from Hardox 450 grade steel, total weight 242 kg. Horizontal bar length – 1m, vertical – 0,52 m, (Picture 1.).

Picture 1. Basic bucket

The results of tests showed, that in general this type of bucket is useful for collecting beach cast algae. It fulfils the most important criteria – dewatering and minimum sand persistence. However, the shape of the bucket was not optimal and has too short vertical bars. These short bars eliminate the amount of algae to be lifted and reduce the productivity of the collection process.

To improve the efficiency of the grate bucket new prototype has designed. New details were plotted, using Solid Works software package for design of mechanical parts. Details were calculated for determine sufficient structural strength, using same software modules for modelling statical loads and tensions. All parts were made using CNC plasma cutting, bending. Assembly of the parts were made by welding. Complete construction was covered by polyurethane paint. Drawings of the parts are given in Annex 3.

The new design grate bucket was (Picture 2) was 1,5m wide, 13 bars with same horizontal and vertical length of 1m, made from hard grade steel, total weight 256 kg.



Picture 2. Improved grate bucket.

Both buckets (basic and improved) have Europe fitting standard for quick fastening. The tractor for tests in both cases was Massey- Fergusson 6615 with front loader.

This is the powerful, new generation of tractors from Massey Ferguson. With unrestricted pulling power for a tractor of this size, the MF 6600 boasts a 4.9 litre AGCO POWER e3 SCR engine producing masses of torque. It is the most powerful medium sized tractor on the market with horsepower up to 185hp with Engine Power Management (EPM)*. EPM allows for the continuous delivery of power under varying conditions to increase productivity. Technical description see Annex 1.

Tests were provided in October 2020 in Liepaja beach, Latvia. Temperature about 10^0 C, no rain.

The first example for tests was MTM type stone bucket, 1,5 m wide, 18 bar with distance of 90 mm, made from Hardox 450 grade steel, total weight 242 kg. Horizontal bar length – 1m, vertical – 0,52 m, - basic bucket (Picture 3).

Picture 3. Loading of algae.

In Picture 3 is moment of loading basic bucket. In average loading process takes 14,1 seconds and depends on terrain and driver skills. From the moment of lifting the bucket intensive dewatering of algae starts, ending with unloading the load in temporary piles on the beach.

Picture 4. Algae transportation.

In Picture 4 transportation to unloading destination is presented, which took in average 13,6 seconds (s) and mainly depend on driving distance. Driving conditions were about the same for every drive -plain sandy beach with variable thickness algae layer covering the surface.

Picture 5. Unloading of algae to intermediate piles.

In Picture 5 unloading algae to temporary deposit pile is presented. Storing algae into temporary piles gives additional important advantage – additional possibility for dewatering of the collected material.

Picture 6. Increased volume of collected algae.

Using improved bucket efficiency of collecting algae increased significantly. The volume of algae, loaded in bucket, always was higher for about 60% to 80% comparing to basic bucket. Loading time was the same. The size of the bucket does not significantly affect the time of loading. Loading time mainly depends of terrain and drivers skills.

Picture 7. Intensive dewatering of algae

Picture 7 illustrates how intensive is dewatering during transportation of the load to temporary pile. Practically all the water leaves bucket due to grated design of it. Dewatering is more intensive in this case, because the amount of algae in bucket is larger, respectively heavier and water is more pressed out of the material. This is additional advantage of improved bucket and thicker layer of the material init.

Picture 8. Intermediate piles

Unloading time for improved bucket in average is the same, only in some cases slightly longer - driver was repeatedly turning the bucket to unload residues and get the bucket clean.

Table 1. Timing records of algae collection on beach. (basic bucket)

Nbr	**Loading**	**Travel to**	**Unloading**	**Travel from**	**Sum**	**Volume**
	s	**s**	**s**	**s**	**s**	**m^3**
1.	8	14	4	17	43	0,3
2.	30	8	7	10	55	0,4
3.	10	11	6	12	39	0,4
4.	12	11	5	15	43	0,3
5.	16	12	6	13	47	0,4
6.	14	16	5	16	51	0,4
7.	12	15	7	16	50	0,4
8.	13	16	6	18	53	0,4
9.	17	16	7	16	56	0,4
10.	9	17	6	18	50	0,4
Total	**141**	**136**	**59**	**151**	**487**	**3,8**

Average	**14,1**	**13,6**	**5,9**	**15,1**	**48,7**	**0,38**

Table 2. Timing records of algae collection on beach. (improved bucket)

Nbr	**Loading**	**Travel to**	**Unloading**	**Travel from**	**Sum**	**Volume**
	s	**s**	**s**	**s**	**s**	**m^3**
1.	6	8	6	12	32	0,6
2.	8	15	9	8	40	0,9
3.	7	15	6	8	36	0,5
4.	10	15	6	10	41	0,5
5.	19	12	7	15	53	0,8
6.	5	12	5	10	32	0,7
7.	10	10	10	11	41	0,9
8.	21	13	6	11	51	0,8
9.	3	15	5	10	33	0,6
10.	5	15	5	15	40	0,7
Total	94	130	65	110	399	7
Average	9,4	13	6,5	11	39,9	0,7

Comparative algae collection tests were performed with a basic bucket and a improved bucket. Time recording of 10 full cycles were made with each bucket.

Each cycle consisted of a total of 4 stages (loading, travel to, unloading, travel from), the duration of which was measured (in seconds). The volume of transferred algae in m^3 was also measured. All the records were exposed in tables.

Given that the change in fuel consumption was so small that it was not possible to identify it, the productivity of each bucket was calculated by replacing this characteristic with 1, according to the formula of productivity.

Productivity = $\frac{V_\Sigma}{t_\Sigma}$ where:

V_Σ= total volume of transported algae (m^3) = V_1+ V_2+...+V_n

t_Σ = the total amount of resources used (h) = t_1+ t_2+..+t

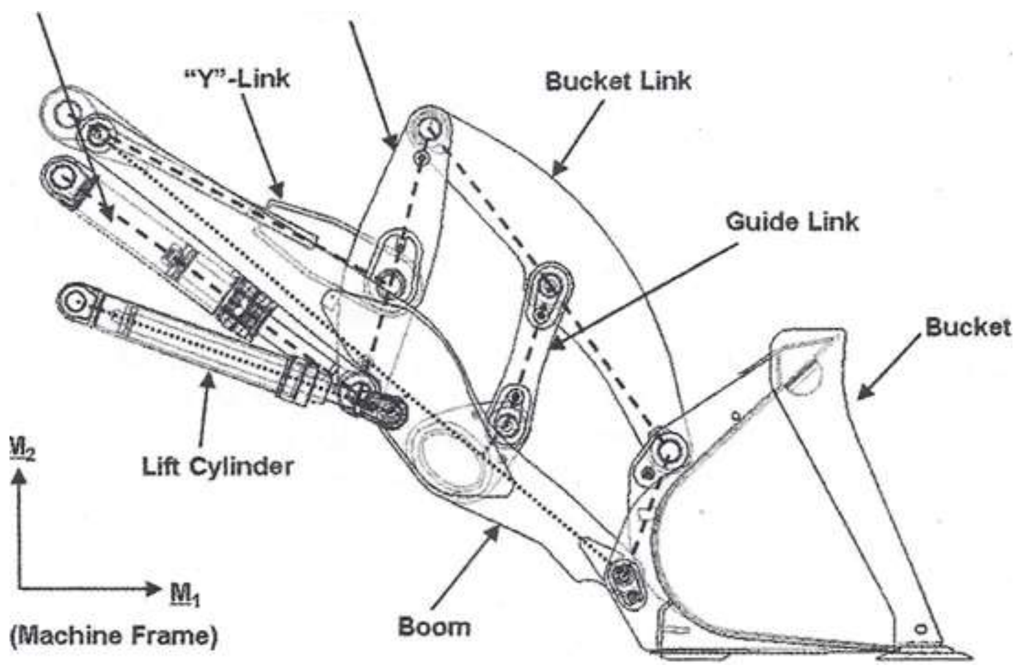
Productivity for the basic bucket = $\frac{3,8}{0,135}$ = 28,15 m^3/h

Productivity for the improved bucket = $\frac{7}{0,11}$ = 63,63 m^3/h

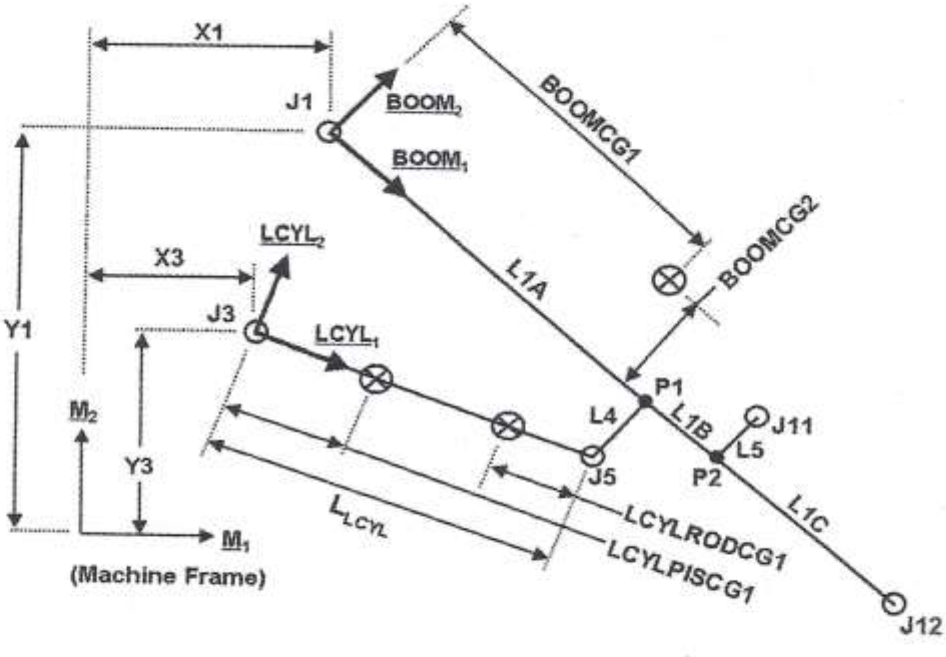
Comparing productivity for a basic bucket versus productivity for an improved bucket = $\frac{63,63}{28,15}$ = 2,26, a result is obtained which proves that the productivity of the improved bucket is 2.26 times higher than that of the small bucket.

3. Mechanism of the bucket

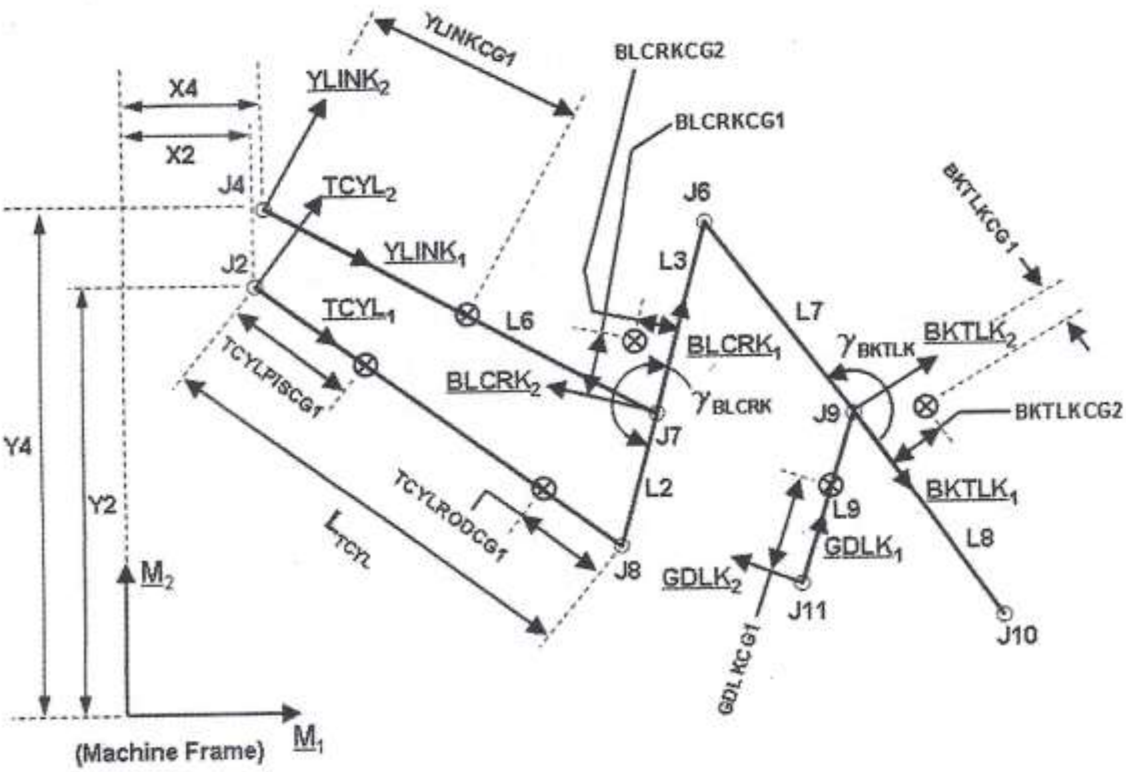
The bucket mechanism considered for this study is shown in Picture 9. It has a relatively new bucket manipulator linkage type, introduced by John Deere in 2004 on its PowerllelTM machines, and was selected because of interest in its unconventional design: the centre pivot joint of the bellcrank is not affixed to the boom structure as in other linkage designs. The bellcrank pivots on a separate link, labelled here as the `Y-link' because the shape of the part's actual design resembles a 'y'. The Y-link pivots in the front frame. For clarity, the underlying kinematic geometry that defines the boom structure and lift cylinder(s) is shown using dotted lines. Similarly, dashed lines indicate the geometries of the bucket manipulator linkage and tilted cylinder.



Picture 9. Schematic picture of bucket mechanism and attached bucket.



Picture 10. Kinematic variables of the boom system.



Picture 11. Kinematic variables of the bucket linkage system.

Pictures 10 and 11 show the boom and bucket linkage systems separated and define the geometrical (kinematic) values required for the overall mechanism model. The mechanism has ten rigid bodies and two degrees of freedom. The equations of motion for the system may be derived with the aid of any commercially available symbolic manipulator. In this case, the program Autolev was used to generate and solve the equations. Due to their length, the equations are not included here. However, a brief description of their set-up is appropriate.

The trivial set of generalized speeds is chosen as shown below:

$$U_1 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(L_{\mathrm{LCYL}}) = \dot{L}_{\mathrm{LCYL}} = v_{\mathrm{LCYL\_ROD}} \tag{1}$$

$$U_2 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(L_{\mathrm{TCYL}}) = \dot{L}_{\mathrm{TCYL}} = v_{\mathrm{TCYL\_ROD}} \tag{2}$$

$$U_3 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{LCYL}}) = \omega_{\mathrm{LCYL}} \tag{3}$$

$$U_4 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{TCYL}}) = \omega_{\mathrm{TCYL}} \tag{4}$$

$$U_5 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{BOOM}}) = \omega_{\mathrm{BOOM}} \tag{5}$$

$$U_6 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{BLCRK}}) = \omega_{\mathrm{BLCRK}} \tag{6}$$

$$U_7 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{BKTLK}}) = \omega_{\mathrm{BKTLK}} \tag{7}$$

$$U_8 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{BKT}}) = \omega_{\mathrm{BKT}} \tag{8}$$

$$U_9 = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{GDLK}}) = \omega_{\mathrm{GDLK}} \tag{9}$$

$$U_{10} = \frac{{}^N\mathrm{d}}{\mathrm{dt}}(\phi_{\mathrm{YLINK}}) = \omega_{\mathrm{YLINK}} \tag{10}$$

The following set of motion constraints apply to the system.

$${}^N\boldsymbol{v}^{\mathrm{J5\_LCYL}} = {}^N\boldsymbol{v}^{\mathrm{J5\_BOOM}} \tag{11}$$

$${}^N\boldsymbol{v}^{\mathrm{J7\_YLINK}} = {}^N\boldsymbol{v}^{\mathrm{J7\_BLCRK}} \tag{12}$$

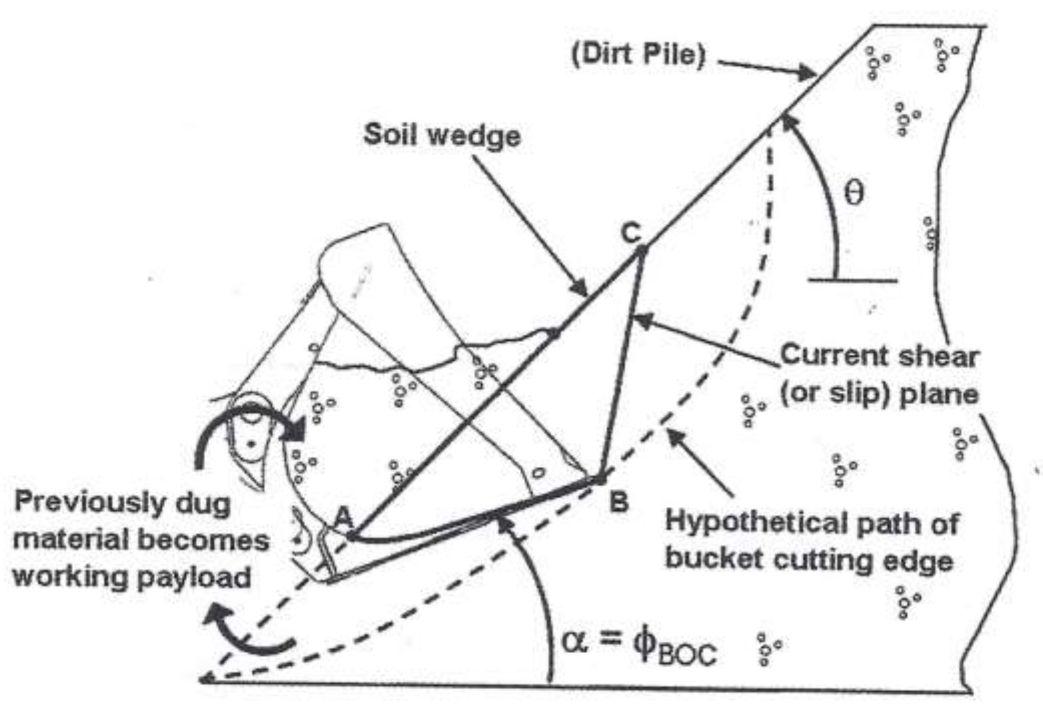
$${}^N\boldsymbol{v}^{\mathrm{J11\_GDLK}} = {}^N\boldsymbol{v}^{\mathrm{J11\_BOOM}} \tag{13}$$

$${}^N\boldsymbol{v}^{\mathrm{J12\_BKT}} = {}^N\boldsymbol{v}^{\mathrm{J12\_BOOM}} \tag{14}$$

Equations (11) to (14) represent eight planar motion constraints, dictating continuity of velocities for joint J5 (belonging to lift cylinder and boom), joint J7 (belonging to bellcrank and Y-link), joint J11 (belonging to guide link and boom), and joint J12 (belonging to boom and bucket). Substituting the generalized speeds U1-U10 in equations (11) to (14) and solving for U1 and U2 as the independent generalized speeds (i.e. the system degrees of freedom), one obtains the necessary dependencies for the generalized speeds Us--U10.

The contributing active and inertial forces in the system include: (a) the weights and inertial loads of the linkage bodies (mass) due to gravity and motional acceleration; (b) the lift cylinder force acting on the boom at joint J5; (c) the tilt cylinder force acting on the bellcrank at joint J8; and (d) the reactive forces on the bucket tool due to digging operations. Therefore, the planar velocities and accelerations of the system bodies and these idealized points of active loading are constructed and used to determine the constrained partial velocities and partial angular velocities. Dot products of these partial velocities with the corresponding active and inertial forces produce expressions for the generalized active and inertial forces, which comprise the equations of motion. The following set of motion constraints apply to the forces generated by the hydraulics as well as the passive earth pressure loads generated on the bucket during digging.

3.1. Digging forces on the bucket



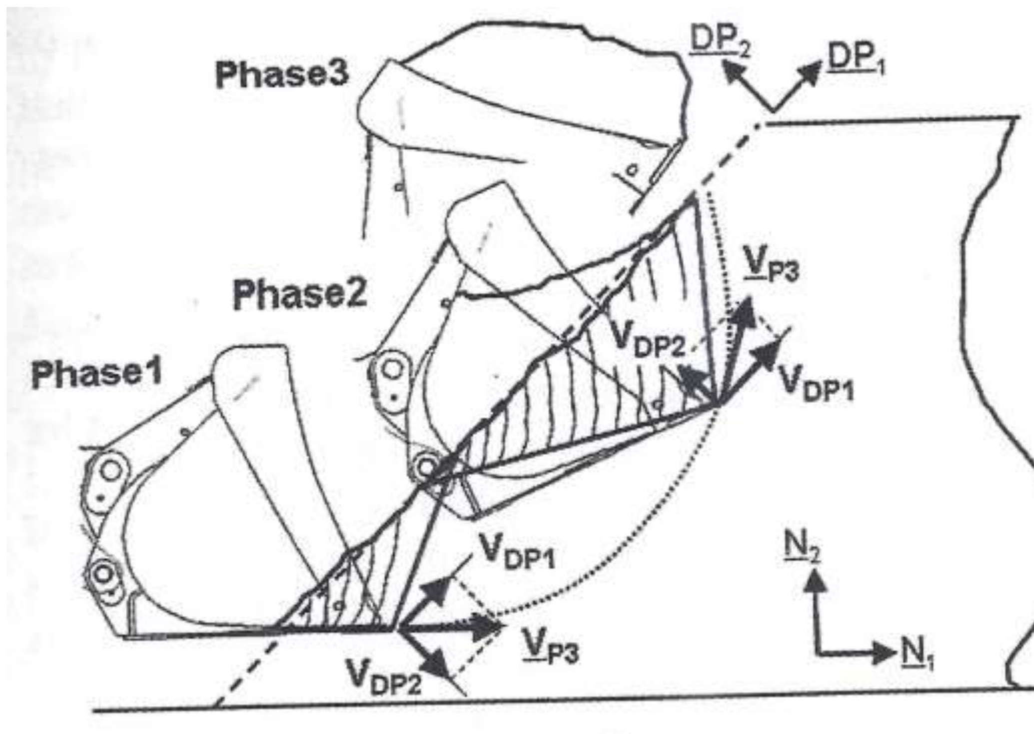
Picture 12. Sketch of bucket tool digging in work pile.

One of the challenging aspects in modelling the behaviour of a wheel loader - or any earthmoving equipment - is capturing the forces produced during digging operations. These forces are primarily dependent on the properties of the soil or rock that is being excavated, which can vary drastically depending on size, composition, temperature, moisture content, compaction, etc. This variability, however, should and does pose a greater challenge to efforts for autonomous excavation and productivity studies, since soil conditions can greatly alter the method of scooping required to achieve optimal performance. For the purposes of structural design the sketch of bucket tool digging in work pile has given in Picture 12.

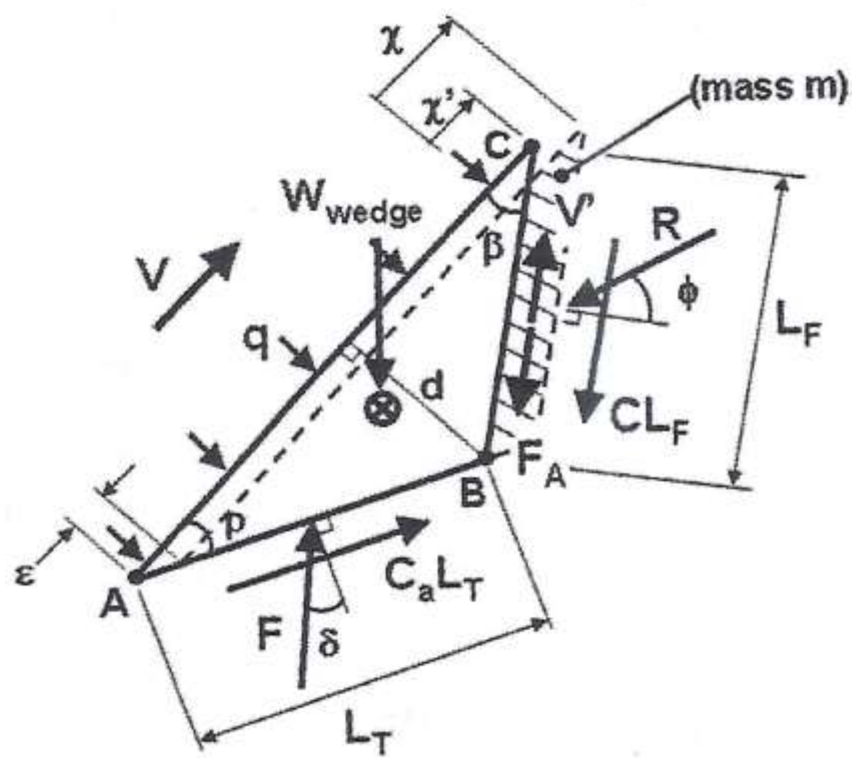
The order of magnitude predictions for standard design cases should suffice. It appears possible to achieve reasonable estimates of the interaction forces between the cutting tool and soil. Furthermore, a two-dimensional model is adequate for the geometries of most bucket tools. The path of the bucket cutting edge is determined by the global vehicle motion.

Penetration into the pile as well as the bucket lift and rotation due to actuation of the lift and tilt cylinders, respectively. The path is not necessarily known a priori and will depend ultimately on operator commands. The 'best' or most productive path may vary from cycle to cycle due to the variability of forces in the digging process created by the soil and/or rock properties.

As previously pointed out, the nature and activation of these loads may change during the digging process due to the variability in soil properties, changes in the contact interface between the bucket and terrain, and the variability in the operator reaction/preference. To simulate loads imparted to the bucket tool throughout the digging process requires making assumptions for all the three. The inaccuracy due to nominal soil properties is considered here as unavoidable. Real time, in situ measurements of the soil properties appear to be the only way to accurately develop these parameters. The items concerning changing tool-soil contact and operator reaction are considered interconnected and are thus treated together in the following discussion.



Picture 13. Three phases of the digging operation

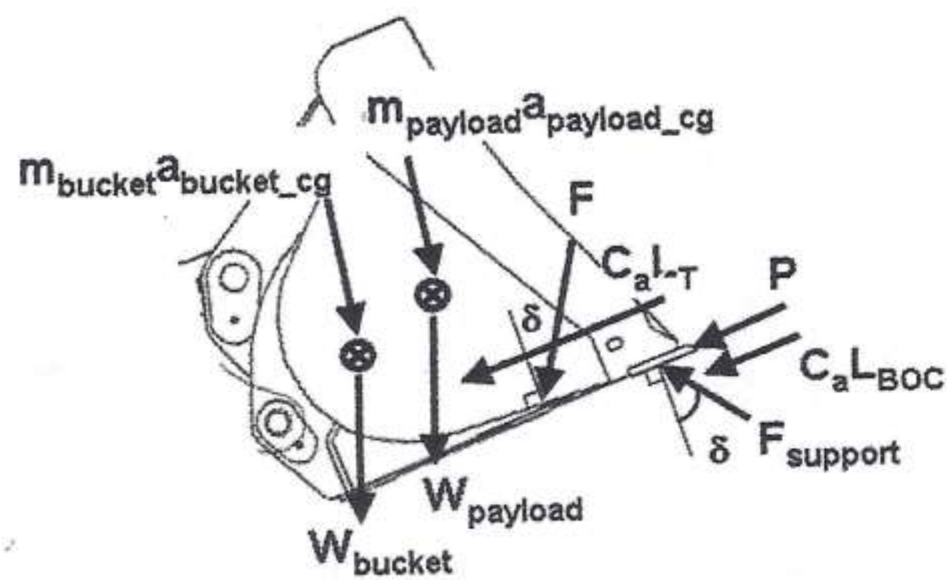


Picture 14. Force diagram of soil wedge

The Sketch in Picture 13 describes the three phases of bucket loading that are assumed in this study. Pictures 14 and 15 describe the interaction loads assumed between the bucket, the soil wedge, and the bulk dirt pile. Not all these forces are necessarily active at the same time during any given phase.

At this point, a discussion of the soil wedge model and associated forces is required. Referring to Figure 14, force F is the combined net normal and frictional force acting between the soil wedge and tool along boundary AB, acting at the angle 8 of soil-to-metal friction. Force C_aLF is the force due to cohesion between the soil and metal along boundary AB. Force R is the combined net normal and frictional force acting between the soil wedge and 'undisturbed' soil along boundary BC, acting at the angle of internal shearing resistance for the soil, 0. Force CLF is the force due to the (apparent) cohesion of the soil along the failure boundary BC. Load q is the surcharge pressure. The angle p = e — a is the rake angle of the cutting edge (commonly referred to as the 'bolt-on-cutting edge', hence the use of the abbreviation BOC in Pictures 9 and 11) relative to the pile surface. This angle changes as the cutting-edge orientation a s altered. At each timestep, a mass m (shown crosshatched in Picture 5) is being added to the bucket and must be accelerated to match the speed of the soil wedge.

Due to the relative motion between the wedge and the bucket tool and referring to Picture 15, the speed V' of the soil mass m is related to the average speed V of the bucket tool cutting plane.



Picture 15. Force diagram of bucket tool

$$V' = \frac{\text{motion of soil mass, } m}{\text{time}} = \left(\frac{\chi'}{\cos\beta}\right)\frac{1}{t} \quad (15)$$

where

$$\chi = \chi' + \varepsilon = \chi'(1 + \tan\beta\cot\rho)$$

Therefore

$$V' = \frac{\chi}{t\cos\beta(1 + \tan\beta\cot\rho)} = \frac{V}{\cos\beta(1 + \tan\beta\cot\rho)} \quad (16)$$

where

$$V = \frac{\text{motion of bucket tool}}{\text{time}} = \left(\frac{\chi}{\cos\beta}\right)\frac{1}{t}$$

$$F_A = m\frac{V'}{t} = V'\frac{\gamma \cdot \chi \cdot \mathrm{d}w}{t} = V'\gamma \cdot V \cdot \mathrm{d}w = \frac{\gamma \cdot V^2 \cdot \mathrm{d}w}{\cos\beta(1 + \tan\beta\cot\rho)} \quad (17)$$

$$F = \left(\gamma \cdot g \cdot d^2 \cdot N_\gamma + C \cdot d \cdot N_C + C_a \cdot d \cdot N_{Ca} + q \cdot d \cdot N_q + \gamma \cdot V^2 \cdot d \cdot N_a\right) \cdot w \quad (18)$$

$$N_\gamma = \frac{(\cot\rho + \cot\beta) \cdot [\sin\theta\cot(\beta + \phi) + \cos\theta]}{2 \cdot \cos(\rho + \delta) + \sin(\rho + \delta)\cot(\beta + \phi)} \quad (19)$$

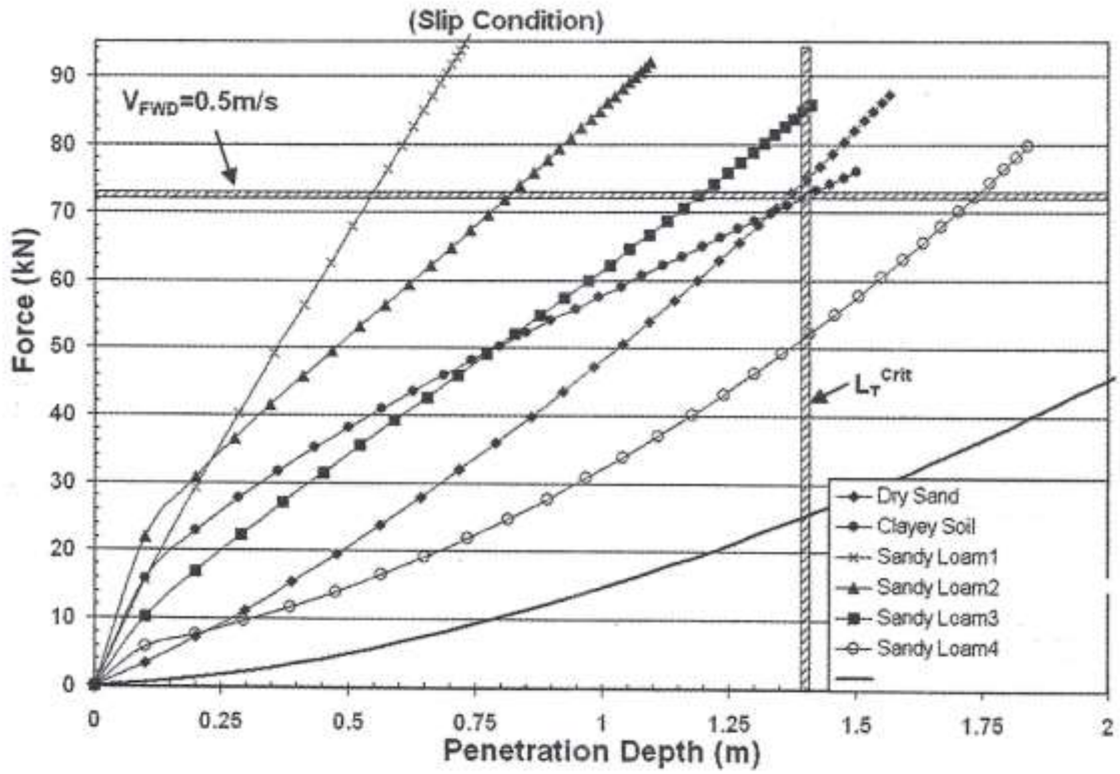
$$N_C = \frac{1 + \cot\beta\cot(\beta + \phi)}{\cos(\rho + \delta) + \sin(\rho + \delta)\cot(\beta + \phi)} \quad (20)$$

$$N_{Ca} = \frac{1 - \cot\rho\cot(\beta + \phi)}{\cos(\rho + \delta) + \sin(\rho + \delta)\cot(\beta + \phi)} \quad (21)$$

$$N_q = 2N_\gamma \quad (22)$$

$$N_a = \frac{\tan\beta + \cot(\beta + \phi)}{[\cos(\rho + \delta) + \sin(\rho + \delta)\cot(\beta + \phi)] \cdot (1 + \tan\beta\cot\rho)} \quad (23)$$

Force F was calculated according to (18) formula and following results were plotted (Picture 16). Continued line indicates collection force of algae material. This force has practical meaning up to 0,5 m of penetration depth (maximal depth of the algae layer on ground).



Picture 16. Relation -penetration depth to force.

Grate bucket has more than necessary robustness and design strength for being used for algae collection.

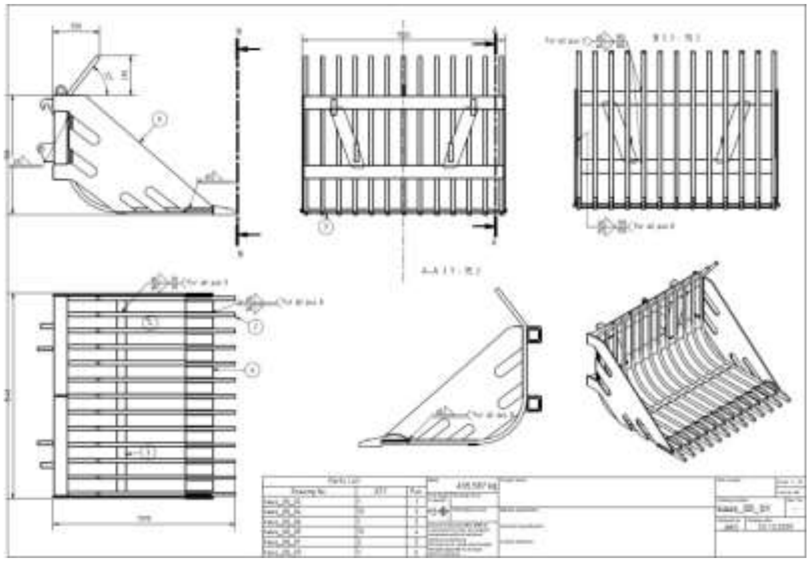
3.2. Description and drawings of the advanced grating bucket

Final Element Analysis (FEA) consists of:

1. Subject definition
2. Subject material properties definition
3. Applied loads and boundary conditions.
4. Review and evaluation of results

Subject definition

This is case study of subject - model with drawing number- kaus_05_01 (Picture 17.)



Picture 17. Drawing “kaus _05_01”.

Subject description and application description:

Model *kaus_05_01* is tractor vehicle front lifter mountable attachment, that fits for earth moving machinery with attachment interface according to ISO 23727:2009-dimensional requirement.

This specific attachment is designed to transport dry hay, dry or wet algae or other beach cast vegetative organic substances.

Purpose of analysis:

Purpose of analysis is evaluating, what will be most optimal physical load for attachment *kaus_05_01* to ensure safe transporting operation during the exploitation.

Subject material properties definition

In the particular analysis, following physical properties of subject *kaus_05_01* were used: material for all parts: **steel - S235 – yield strength 235 MPa.**

Also, we are taking into account that all welding work for this subject *kaus_05_01*: is made according to ISO 5817:2014 level C.

Applied loads and boundary conditions

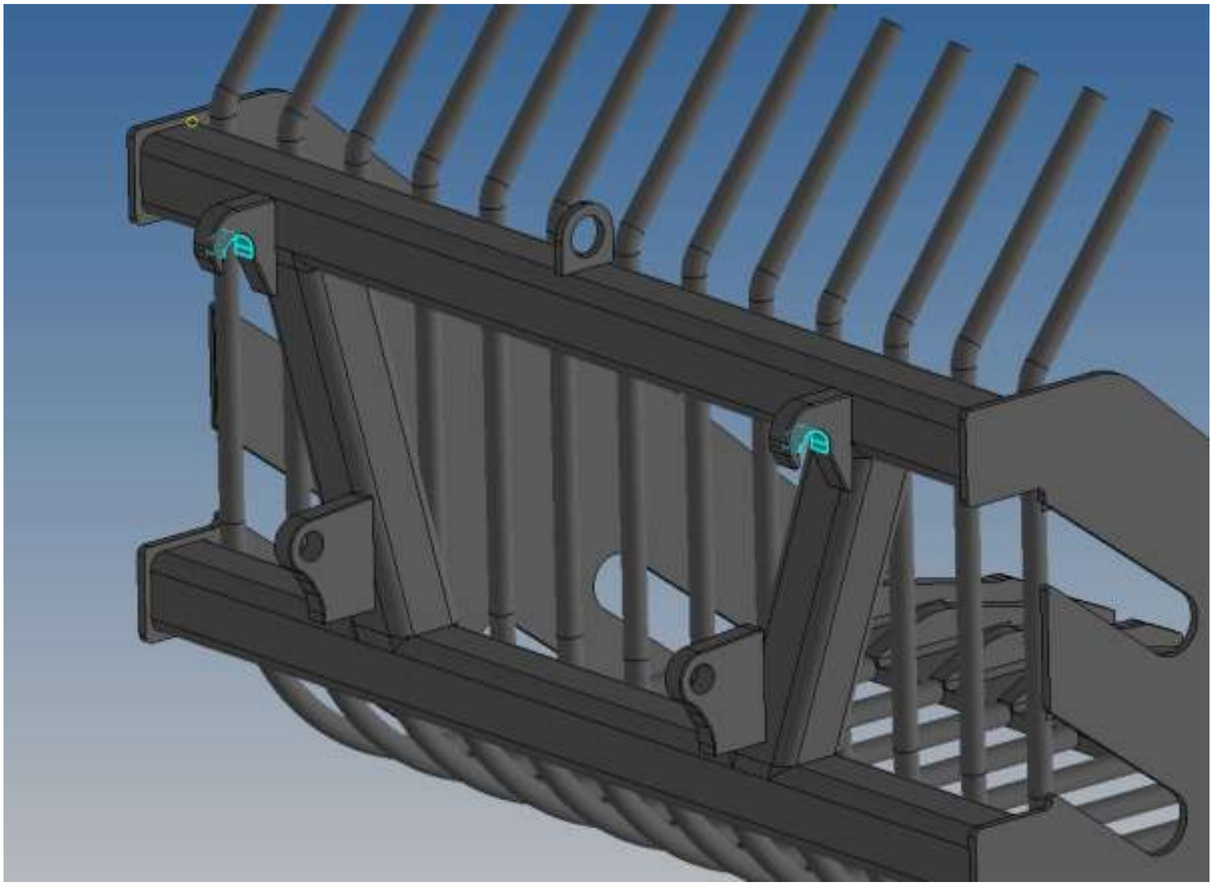
Fixation definition for analysis:

In this study static analysis will be done and two types of constrains **Fixed** and **Pin**

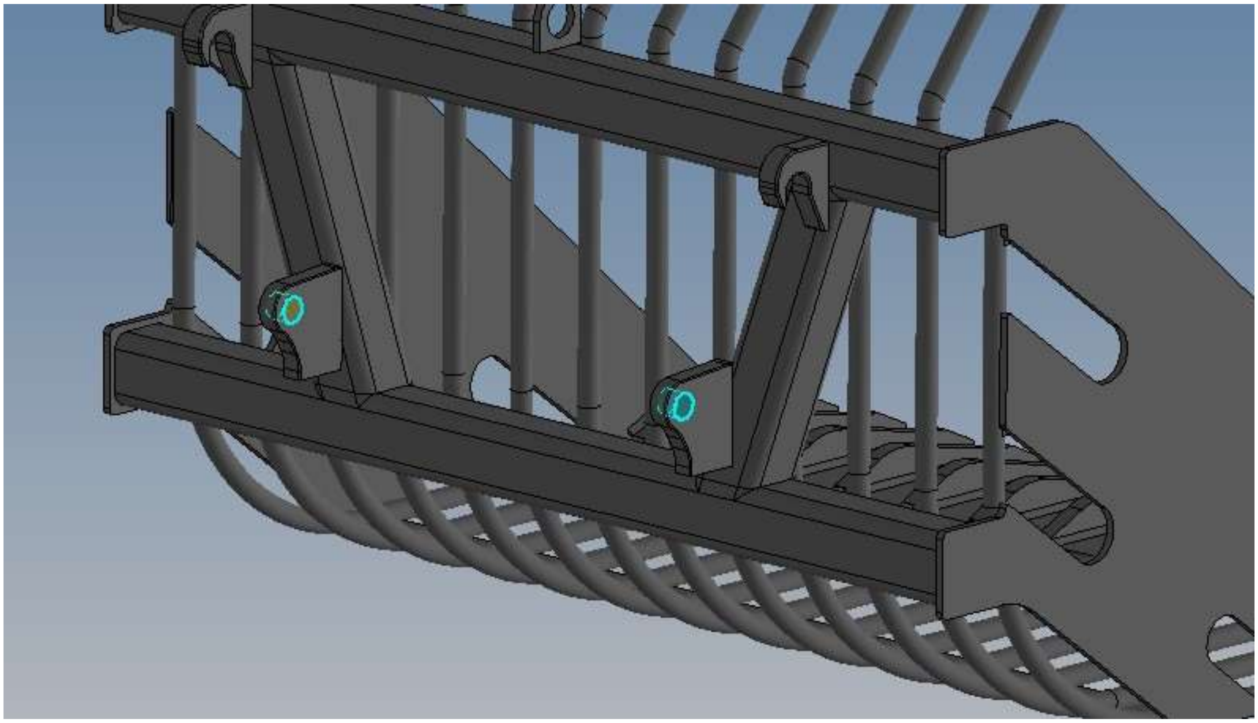
Fixed will be used – marked surfaces are considered as fixed (not movable) surfaces.

(Picture 18).

Pin – marked surfaces are considered as fixed in place surfaces, but will be allowed for radial, axial, or tangential direction motion (Picture 19).



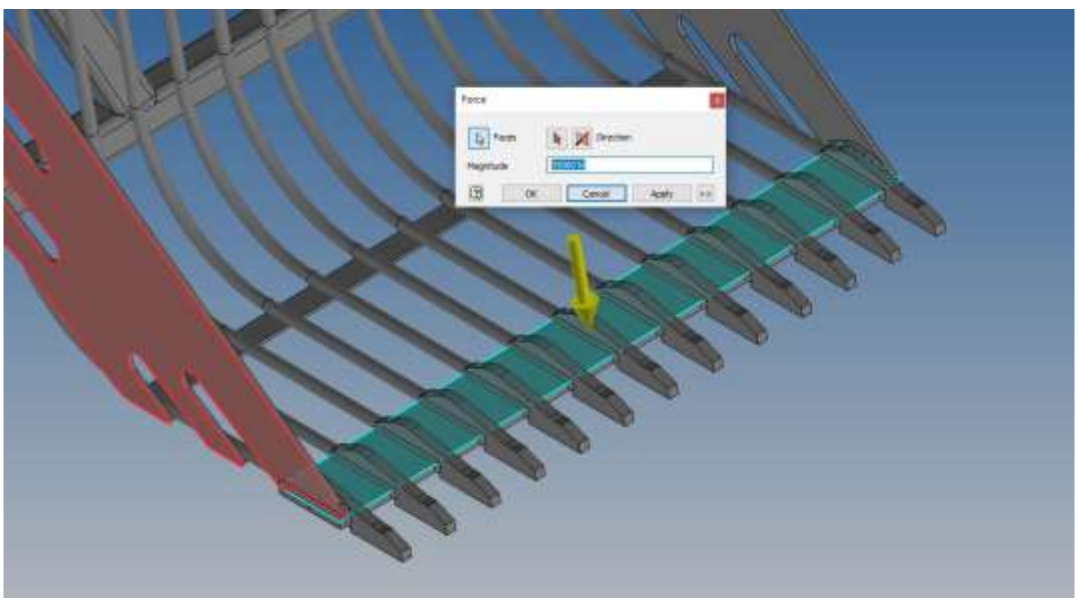
Picture 18. Fixed surfaces.



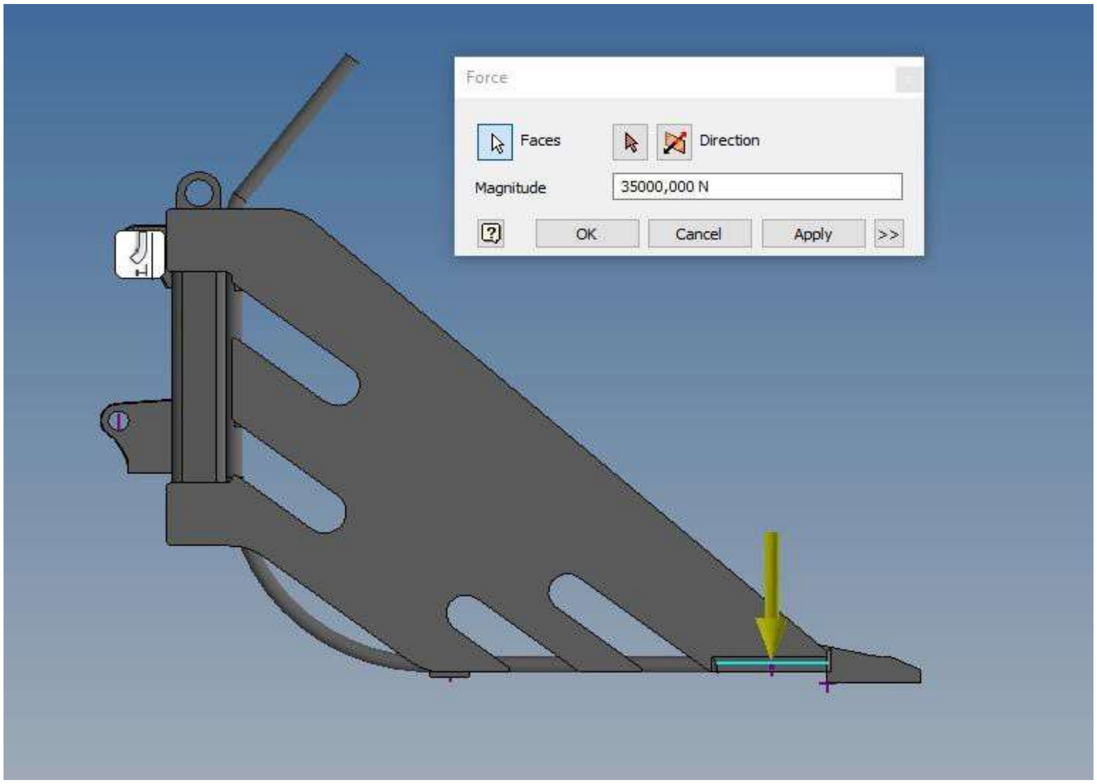
Picture 19. Pin surfaces.

In the study load is applied in locations, where it will create the greatest momentum of force in relation to the mounting location.

As example, 30kN force is applied to the surface, all force is distributed evenly through all surface (Pictures 20 and 21).



Picture 20. Applied forces.



Picture 21 Applied forces (cross section).

Review and evaluation of results

After applying the force, boundary maximums yield strength has been setting. It is known that material maximum yield strength is 235 MPa, to eliminate probability of some geometrical miscalculation, yield strength boundary has been setting to 220 MPa.

After completion the calculation, one can see that the most critical surface is in the location where force is applied (Picture 22 and 23).

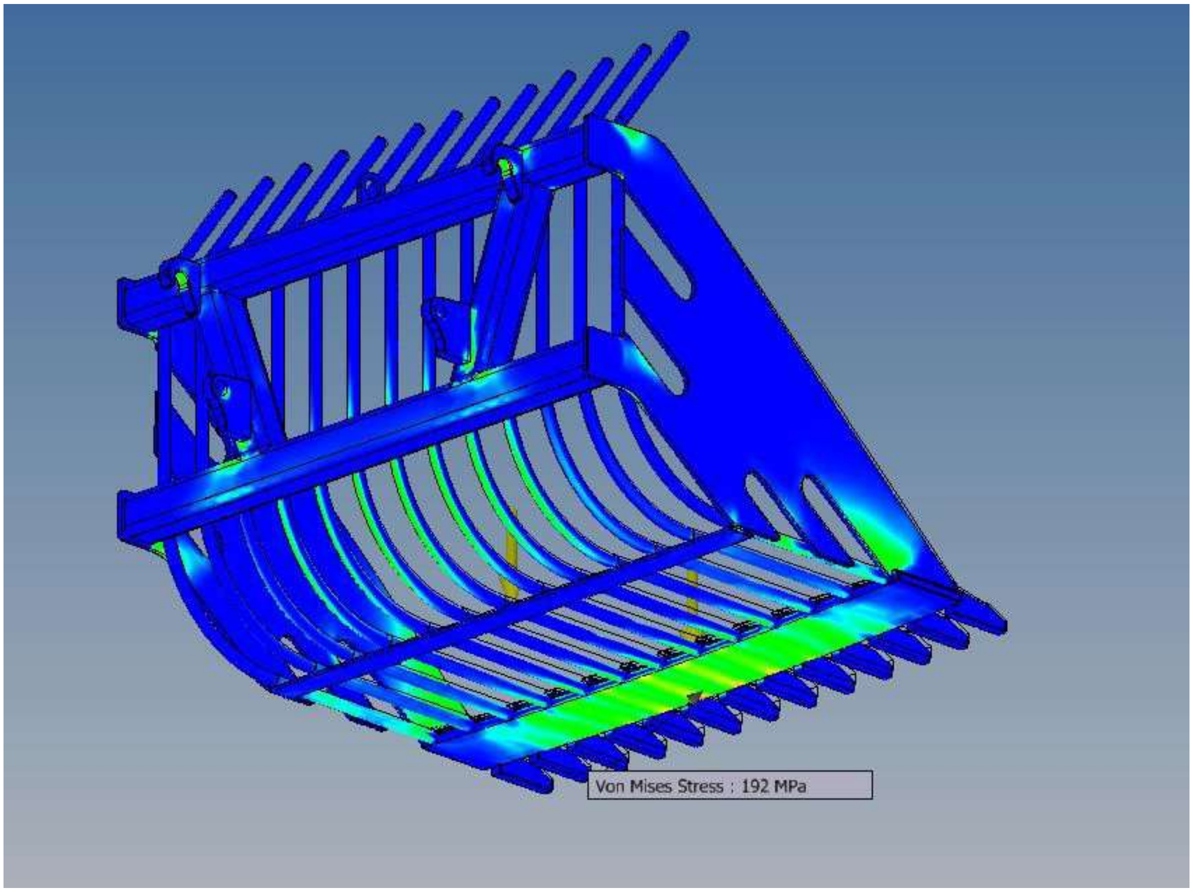
In that location we can see that the maximum Von Mises Stress is 192MPa and that it does not exceed the threshold, that was set in the beginning.

Displacement at the location where the force will be applied is around 20mm. But as Von Mises Stress does not go over 235MPa, it means, that after the removal of load construction will regain its original geometrical location (Picture 24).

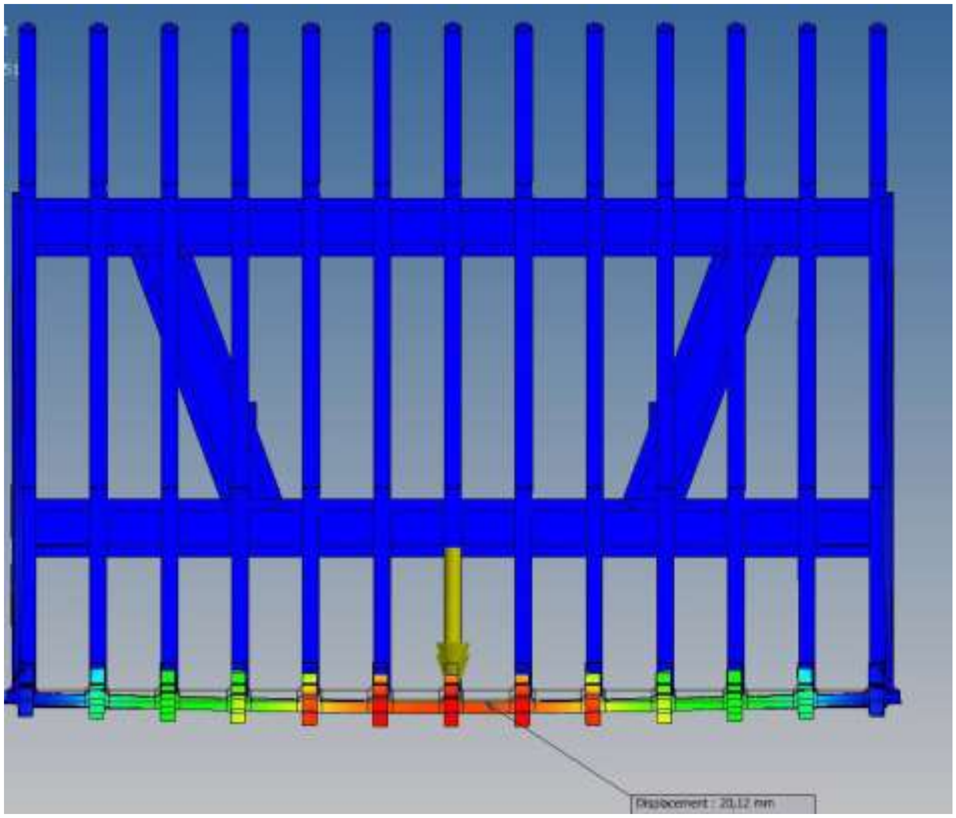
One can observe the lowest safety factor value on the middle of surface where the force was applied. Construction still have Safety factor 1,23 in this location and it means 35kN force is the highest load that this construction can take and regular operation in maximum load conditions is not recommended - it can cause irreversible deformation and even collapse of construction over time.

Conclusions:

Subject *kaus_05_01 is* made completely from steel S235. Can hold force up to 35kN, but it is the total limit for this construction. In exploitation documentation we are suggesting to use maximal load capacity not higher than 25kN. That will prevent construction from unexpected overload, which can cause irreversible deformation. Also setting maximum operation load up to 25kN will prevent steel from fatigue deformation and damage.



Picture 22. Tensions in force applied areas.



Picture 23. Construction geometrical condition.

4. Improved grate bucket prototype design

Picture 24. Grate bucket prototype (front view)

In Picture 24 the 3D model of improved grate bucked is given , designed and rendered, using software package SolidWorks. Improved bucked has 13 longer vertical branches. This improvement allows to enlarge the capacity of the bucket and increase overall efficiency of collecting process. Mounting fixtures comply to “Euro” (ISO 23727:2009) standard and allows fast mounting/unmounting of grate bucket. All metal parts are manufactured using CNC equipment, from hard steel alloy.

5. Operation instructions for grate bucket

Even the grate bucket is not high- tech device, it has to be regarded with adequate respect, because it could be dangerous enough in specific exploitation situations.

Most important.

Most important in safe use of grate bucket is the **bucket fixing safety**. Driver has to be aware that grate connected to front loader has safe, adequate connection. When the connection is loose, the work has to be terminated until connection is fixed.

The same importance has **intermediate connection modules, used from transition from one fixture standards to another**. Stable and solid connections have to be achieved in the connections of intermediate module, bucket and front loader.

It is also important to move the bucket carefully, in case due the device weight (more 200kg) could cause injuries in interaction with service staff.

During loading, traveling and unloading it is forbidden for service staff to stay in loading area.

6. Recommendations

Always wash the bucket before storing to remove salt remains, because salt water is causing rapid corrosion of the bucket.

Cower metal parts with silicone grease or other protective material.

Store the bucket when it is dry.

See full safety instructions in Annex 2.

7. Overall description of the collection techniques for algae beach cast biomass in Kurzeme region

Most efficient machinery for collecting algae from sandy beaches, as far as it is investigated, is front- loader equipped with grate bucket. Algae collecting methods itself has some importance, too. In this study one method has been studied that, in our opinion, have some advantages. This method has 3 stages of operation:

1. Algae collection in temporary piles on the slope of the coast;
2. Flattening the piles and making uniform algae layer;
3. Additional option-using straw press to pick and compress the algae.

Collecting algae in temporary piles helps to maximally remove the water out of the material and have it collected as much as possible dry. If the pressing equipment is used, the uniform layer gives good opportunity to pick up algae efficiently and with good productivity (Picture 26).

Picture 25. Intermediate piles.

Improved grate bucket allows collect algae from beach and load it to intermediate piles efficiently and in good quality. The collected amount of algae is 2,26 times more, comparing to basic bucket. Collected material has less moisture, because improved bucket has bigger volume of loaded algae, its layer is thicker and heavier than in case of basic bucket. This initiate additional pressure in algae mass and increases dewatering of algae. Forming intermediate piles has no certain restrictions, but in practice piles are about 2 meters high and in 10 – 12 meters one from another. If it is planned to load algae directly from intermediate pile to transport, then flattened layer is omitted and algae are loaded by frontal loaders directly to lorries or trailers. Using intermediate piles allows flexible planning transporting schedule because loading and transporting are not anymore tightened. Advantages of the improved bucket makes collection of algae much efficient comparing to use of basic bucket.

Picture 26. Flattened piles to layer of algae.

Formation of flattened layer of algae is meaningful only, if collecting algae from sand is planned by rotor type machines, like straw press.

To test usefulness of straw presses, the roll type straw press was tested. The results of tests showed good algae pick up performance of straw press CLAAS 62 (Picture 27), but it was useless to press algae. The fibres of algae were too short to form bales. The results of experiments shows that it is necessary to continue research – change the construction and repeat the tests. Unfortunately, without construction changes straw press is not useful for pressing the algae.

Picture 28. Picking algae by straw press.

8. Opportunities of commercialization

Collection of algae using improved grate bucket is viable and has potential of commercialization. Improved grate bucket could be used by fishermen or farmers, interested in collecting algae biomass. Possibility of using bucket for handling other materials is additional gain. Improved bucket can be used for handling hay, straw, branches, firewood, gravel and small stone collection. Eventual price for improved bucket (700-800 EUR) could be acceptable and economically fairable for potential customers. Improved bucket can be made in well equiped metalworking shop who has CNC bending, cutting and welding equipment.
In case of COVID-19 pandemic situation most optimal type of production – on distant request and delivery by transport companies or by own transport.

Conclusion

- One of the most suitable tools for collecting beach cast algae is front loader, equipped with grate bucket.
- Size of bucket determines the overall efficiency of collecting process. The total weight of the load of algae biomass is lower than the capacity of tractor, so bigger bucket yields higher output
- To increase efficiency of the bucket, the design of the bucket was changed – vertical branches have been prolonged, increasing its capacity.
- When changing design of the bucket, the mechanical strength must be checked. The most appropriate is to use final element analysis. The results of the analysis confirmed the mechanical strength of modified design.
- Using designing software package “SolidWorks” for metal parts is possible to create 3D drawings of metal parts, production files for CNC machines and in the same time check parts foe mechanical strength.
- Testing the improved grate bucket showed the increase of efficiency of algae biomass collection by 2.26 times comparing to base bucket.
- Collecting algae to intermediate piles lead to efficient moisture drainage and eases the transport schedule planning.
- The design of improved backet allows to make it in metal workshop, equipped with CNC equipment. It determines good commercialization opportunities and fair market price.
- The commercialization opportunities are increased also by additional use possibilities of handling hay, straw firewood, sorting and transportation of stones and gravel.

Literature

1. Study “Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality”. Viewed in 31.07.2019. Retrieved from http://wabproject.pl/files/Technological%20solutions%20for%20the%20collection%20and%20remova l%20of%20al gae%20from%20the%20beach,%20sea%20and%20coastal%20strip%20in%20Trelleborg%20Mu nicipality%20%20 ENGLISH.pdf
2. Worley, M. D., La Saponara*, V. “A Simplified Dynamic Model for Front-end Loader Design”, 2008, Journal of Mechanical Engineering Science (Proceedings of the Institution of Mechanical Engineers, Part C), 222, pp. 2231-2249.
3. Institute of Scrap Recycling Industries www.isri.org ;www.isrisafety.org.

Annex 1. Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD

Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
Version of the model:		
	Drive:	4 Wheel drive
	Production year:	
	From:	2013
Engine:		
	Brand:	Agco Power
	Type:	4 stroke
	Engine cooled:	water cooled
	Cylinders:	4
	Aspiration:	turbocharged
	Intercooled:	Air to air cooled
	Emission level:	Tier 4
	Power:	
	Gross:	107.00Kw / 143.49Hp
	with PowerBoost:	117.50Kw / 157.57Hp
	Power at:	1950rpm

Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
	Torque:	
	Maximum (SAE):	652.00Nm / 482.48lb-ft
	with PowerBoost:	670.00Nm / 495.80lb-ft
	Max. torque at:	1500rpm
	Displacement:	4,900cm³ / 299ci³
	Fuel:	diesel
	Fuel system:	high-pressure common rail injection
Electrical system:		
	Power source:	
	System:	12V
Hydraulic system:		
	Hydraulic pump:	
	Main pump:	58.00L/m / 15.32gpm
	Optional main pump:	
	Flow capacity:	110.00L/m / 29.06gpm
	Number of control valves:	4
	Hydraulic pressure:	

Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
	Working hydraulics:	200.00Bar / 20.00Mpa
Transmission & speed:		
	Make:	Massey Ferguson
	Gearbox:	Dyna-4
	Powertrain:	4 Wheel Drive
	Transmission:	
	Gears:	Semi-powershift gearbox
	Forward gears:	16
	Reverse gears:	16
	Travel speed:	
	max first gear:	1.30km/h / 0.81mph
	Maximum speed:	40.00km/h / 24.85mph
	Creeper:	0.33km/h / 0.21mph
	Optional transmission:	
	Gears:	Supercreep
	Forward gears:	32
	Reverse gears:	32

Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
	Power takeoff:	
	Type:	Independent / Electro hydraulic control
	PTO speed:	540/1000rpm
	Engine at PTO speed:	1980/2030rpm
	Speed front:	1000rpm
Braking system:		
	Service brake:	Electro hydraulic / Oil cooled
Service refill capacities:		
	Fuel tank:	250.00L / 66.05US gal
	AdBlue:	30.00L / 7.93US gal
Dimensions:		
	Transport dimensions:	
	Length:	4,715mm / 186Inch
	Heigth:	3,080mm / 121Inch
	Height dimensions:	
	Cabine:	
	Height:	3,080mm / 121Inch

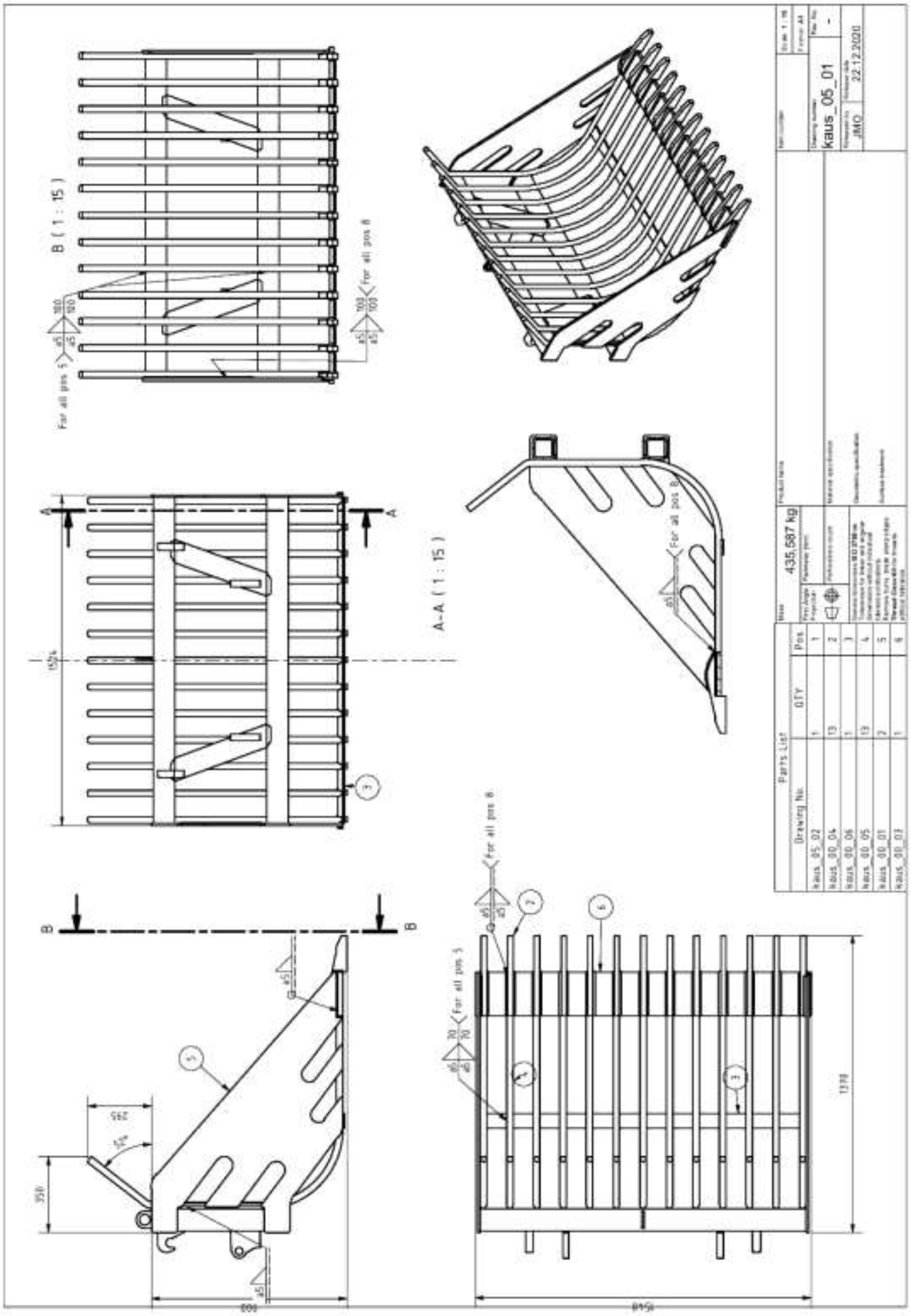
Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
	Ground clearance:	
	Centre of wheel-base:	435mm / 17Inch
	Wheels & tyres:	
	Tire size:	
	Front:	16.9 R28
	Rear:	20.8 R38
	Wheelbase:	
	Length:	2,670.00mm / 105.12Inch
	Steering:	
	Steering method:	2 Wheel steering
	Steering system:	Hydrostatic
	Turning radius:	
	Outside of tire:	4,250mm / 167Inch
Performance:		
	Lifting capacity:	
	Lift capacity rear:	7,100kg / 15,620Lbs
	Lift capacity front:	3,200kg / 7,040Lbs

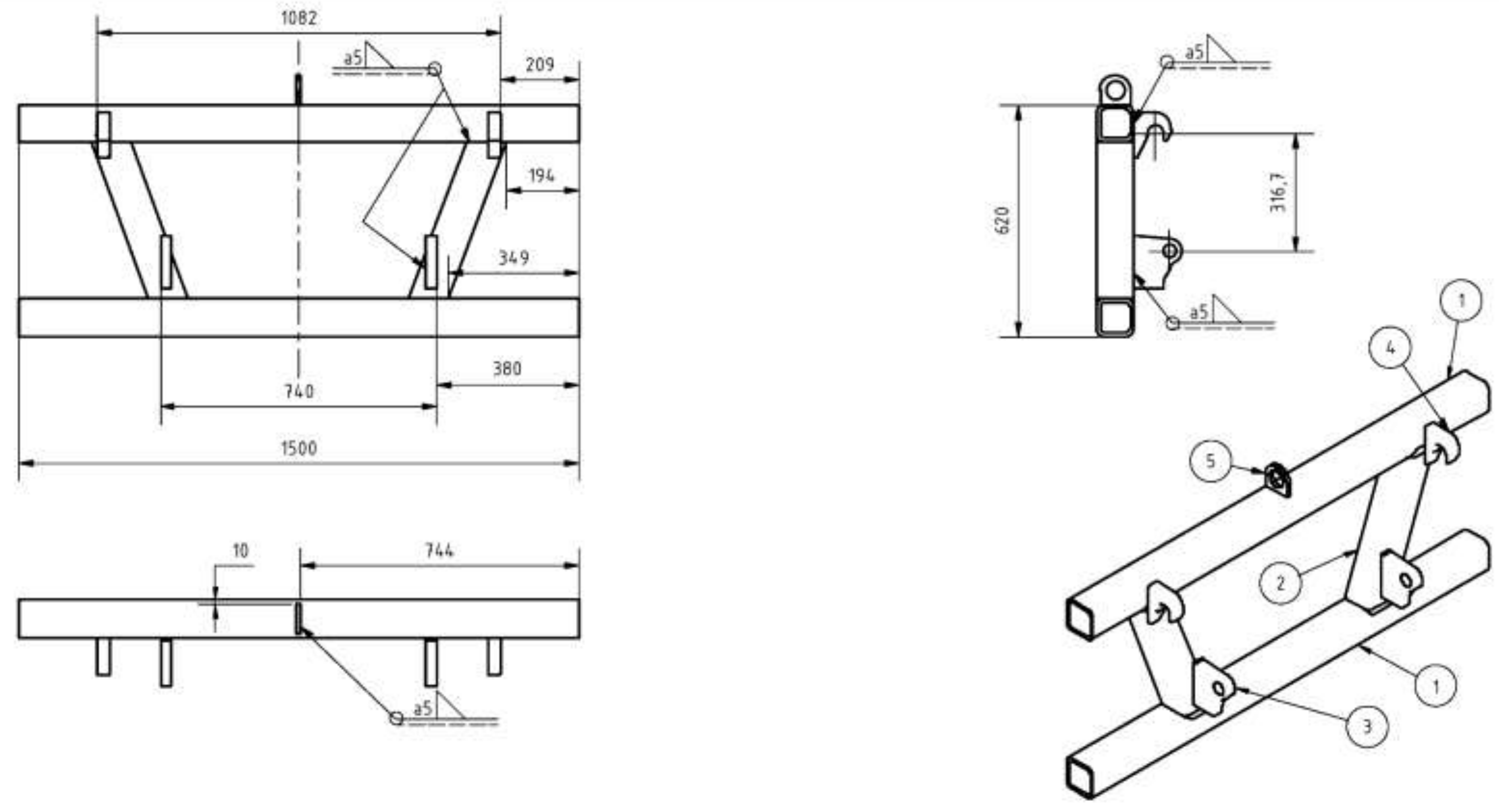
Technical Specifications MASSEY FERGUSON 6615 DYNA-4 4WD		
Weight:		
	Operating weight:	
	Operating weight:	5,700kg / 12,540Lbs
	Without ballast:	5,700kg / 12,540Lbs

Annex 2. General safety precautions for front-loaders

- Never walk or work under a raised loader.
- Raise and lower loader arms slowly and steadily.
- Allow for the extra length of the loader when making turns.
- Take extra precaution when handling loose loads.
- Never move or swing a load while people are in the work area.
- Stay away from the outer edge when working along high banks and slopes.
- Watch for overhead wires and obstacles when you raise the loader.
- Travel with the load low to the ground and watch for obstructions on the ground.
- Operate the loader from the operator’s seat only.
- Do not lift or carry anyone on the loader, bucket or attachments.
- Lower the loader when parking or servicing.
- Assure all parked loaders are on a firm, level surface and all safety devices are engaged.
- Visually check for hydraulic leaks and broken, missing or malfunctioning parts, then make necessary repairs.
- Under pressure, escaping hydraulic oil can have sufficient force to penetrate the skin, causing serious personal injury. Injuries resulting from oil penetrating the skin are very difficult to treat. Use a piece of cardboard or paper to check for pinhole leaks.
- Before disconnecting hydraulic lines, relieve all hydraulic pressure.
- Be certain anyone operating the loader is aware of safe operating practices and potential hazards.
- Extending the tines of a loader may look like a good way to solve the loading problem, but when this is done, the tractor’s centre of gravity is moved forward. Extra stress is placed on the loader, the hydraulic system and tractor front end.
- All loaders should have roll-over protective structures (ROPS). ROPS can either be a protective enclosed cab or a roll bar with a canopy.
- Loader operators should wear the seat belt at all times, regardless of the task that is being done.[3]

Annex 3. Drawing of improved bucket.





Parts List		
Drawing No.	QTY	Pos.
kaus_00_02	2	1
kaus_00_07	2	2
kaus_00_10	2	3
kaus_00_09	2	4
kaus_00_08	1	5

Mass 112,7 kg

First Angle Projection

Perimeter [mm]

Perforations count

General tolerances ISO 2768-m. Tolerances for linear and angular dimensions without individual tolerance indications. Remove burrs, break sharp edges. Thread Class 6H for threads without tolerance

Product name

Material specification

Geometric specification

Surface treatment

Item number

Scale 1 : 15

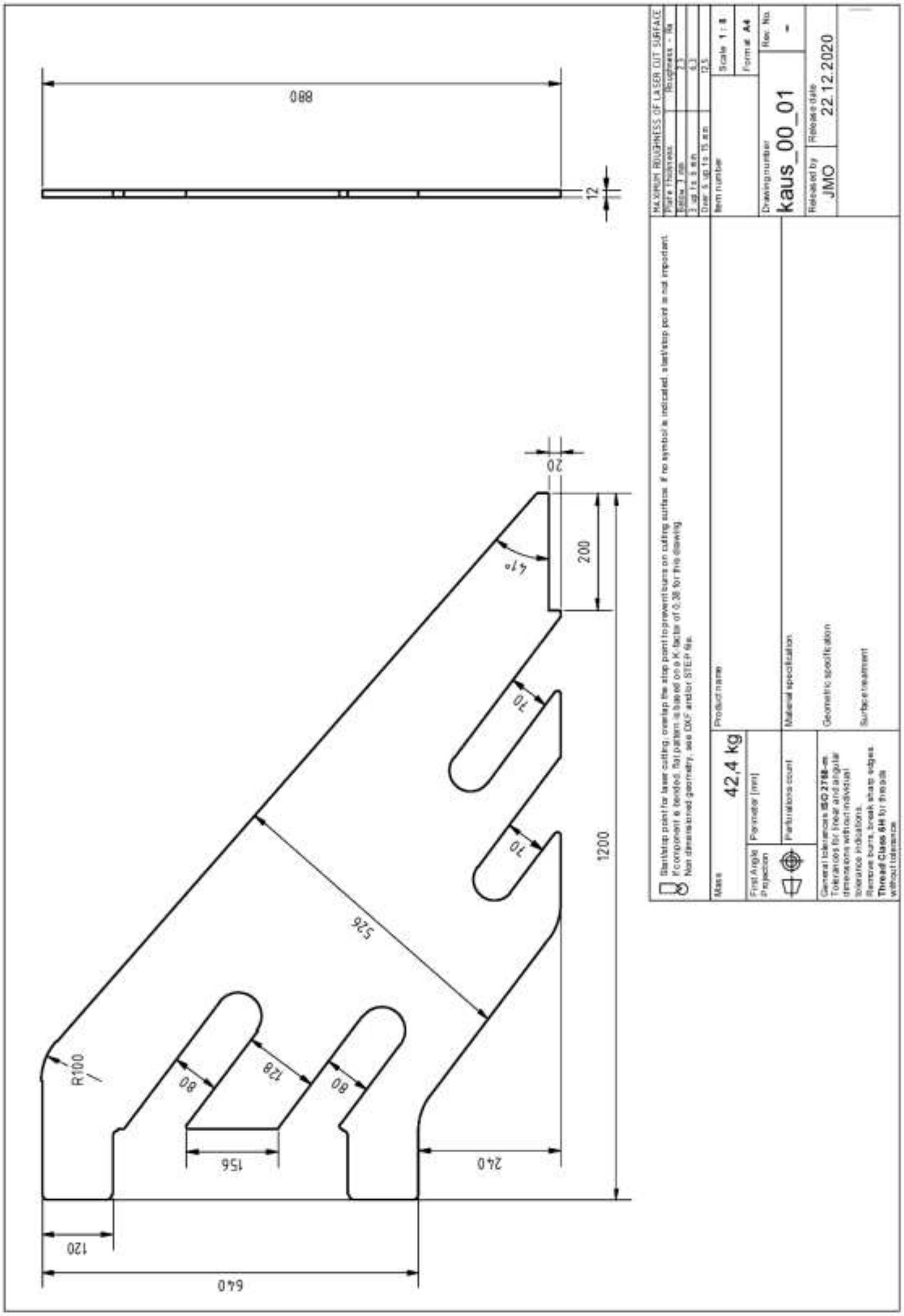
Format A4

Drawing number kaus_05_02

Rev. No. -

Released by JMO

Release date 22.12.2020


880
12
20
200
41°
70
70
1200
526
R100
80
128
80
156
240
120
640
Mass
42,4 kg
Product name
Drawing number
kaus_00_01
Released by
JMO
Release date
22.12.2020
Scale 1:8
Format A4
Rev. No.
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