DETERMINATION CENTRE OF PERCUSSION FOR HAMMER MILL HAMMERS

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Abstract. Herbaceous biomass potential is considered as a valuable local renewable energy resource in Latvia. Cereal crop straw (mainly wheat straw), common reeds, rape straw and reed canary grass are the most prospective stalk materials for solid biofuel production. The main biomass conditioning operation in solid biofuel production technology is shredding. Hammer mills are the essential equipment for this operation. Hammers and their articulation are rapidly wearing during hammer mill lifetime. It is recommended to design hammers so that collisions with biomass particles are applied in the hammer centre of percussion. Then the hammer articulation hole is less wearing, unbalance and vibration of the hammer mill rotor are avoided. The main objective of this paper is to determine compliance with this rule for different size rectangular style manufactured hammers. Calculations were made using the Mathcad program for four different size hammers. Only for one size hammer positioning of articulation partly accomplished the mentioned recommended condition of the hammer centre of percussion. The recommended positions and sizes of articulation holes were determined for the mentioned four size hammers. If the hammer design accomplishes the recommended condition of the hammer centre of percussion, it is possible for collisions with particles during milling in different points of the hammer. Then some impact forces in the hammer articulation hole will appear. Therefore, it can be concluded that, if the centre of percussion is designed at the end part of the hammer, the impact forces in hammer articulation would be minimized. The results of calculation in compliance of four sizes of manufactured hammers with the condition of the centre of percussion at the end point of the hammer show that only one hammer size partly satisfies this condition. This shows that the hammer mill hammer design so that interaction between the hammer and material occur at the percussion centre of the hammer is still actual. The sizes of articulation holes have to be also calculated in accordance with the pin shaft strength conditions. Changing the size of the articulation holes the articulation position must be changed.

Keywords: hammer mill hammers, centre of percussion.

Introduction

Hammer mills are the essential equipment for herbaceous biomass shredding before compacting as solid biofuel. Hammers are the main working tools of the hammer mill and are rapidly wearing during the hammer mill lifetime. The percussion interaction between the hammer and material produce additional perturbations generating irregularities [1] during the work. This leads to the consideration of the hammer design so that interaction between the hammer and material occur at the percussion centre of the hammer [2; 3], then the percussions in the articulation are eliminated and so the work of the machine is not disturbed.

The main aim of this paper is to determine compliance with this rule for different size rectangular style existing manufactured hammers. The articulation hole sizes have to be also calculated in accordance with the pin shaft strength conditions. Changing the articulation hole size the articulation position also must be changed.

Materials and methods

The cutting tool of the hammer mill is shown in Fig. 1. The main parts of it are the cutter head 1 and sieve 2. The cutter head 1 contains attached to it knives 3 and hammers 4. The knives are made primarily for shredding of biomass, but the hammers against a sieve make final shredding of biomass. There are different shapes and sizes of hammers, but very often the rectangular shape hammers with two symmetrically placed holes for articulation to the cutter head are used.

The construction with two mounting holes (Fig. 2) allows four mounting options of the hammer during its time of wear [4]. This means that two holes allow up to four working corners versus two on a single hole hammer. For implementation the condition of the centre of percussion [2] at the point *A* at the end of the hammer, if the articulation is in point $O_{1,}$ the equation is used:

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$$f(\xi, r) = \left[\xi - h + \frac{b \cdot h \left[\frac{h^2}{12} + \left(\frac{h}{2} - \xi \right)^2 \right] - \pi \cdot r^2 \left[\frac{r^2}{2} + (h - 2\xi)^2 \right]}{b \cdot h \left(\frac{h}{2} - \xi \right) - r^2 \cdot \pi (h - 2\xi)} \right] = 0, \tag{1}$$

where ξ – distance from rectangular hammer end to hole centre, mm (see in Fig. 2);
r_1, r_2 – radii of holes, mm;
h – hammer length, mm;
b – hammer width, mm.

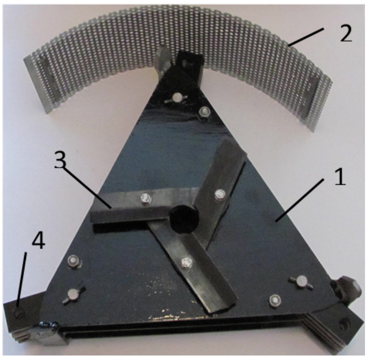


Fig. 1. **Hammer mill cutter head and sieve**

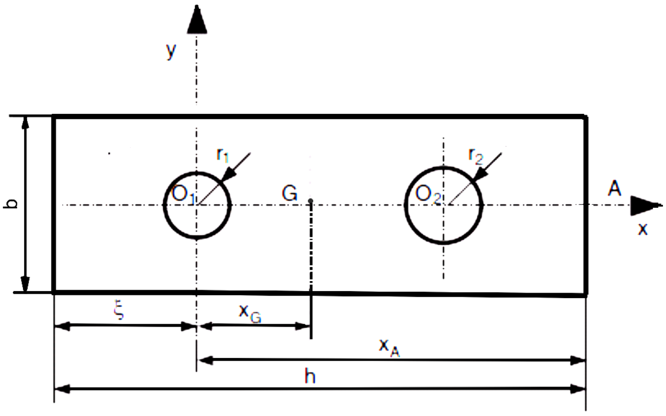
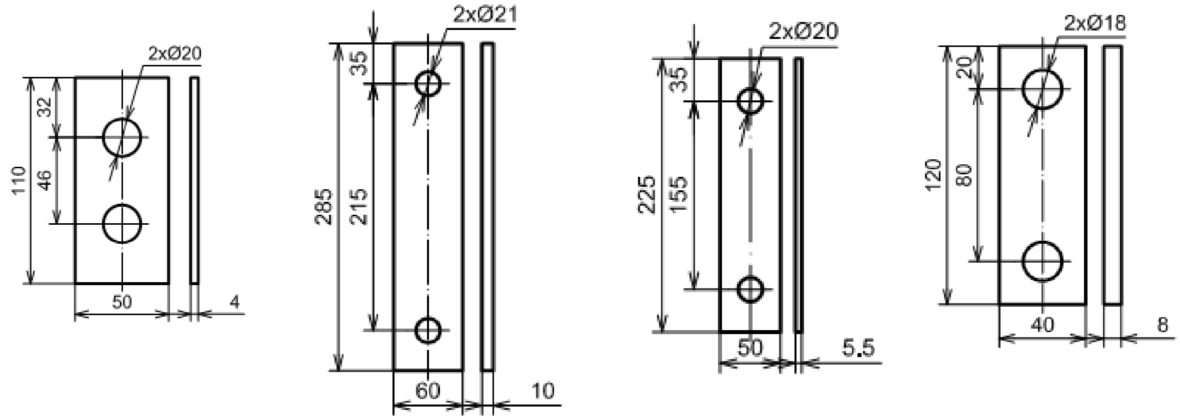


Fig. 2. **Rectangular hammer with two articulation holes**

The aim of this investigation was to determine the compliance with this rule (1) of four different size rectangular style manufactured hammers. Their sizes are shown in Fig. 3. The sizes of hammers in Fig.3 a, b and c are obtained from literature [1], but the size of the hammer in Fig. 3 d is from Peruzzo hammer mill (see also the cutter head in Fig. 1). During calculation equation (1) with Mathcad program equal size of hammer articulation holes $r_1 = r_2 = r$ was used. The left side part of the equation as the function of two parameters $f(\xi, r)$ and other sizes of hammers in Fig. 3 had been calculated. The distance ξ and radii r of articulation holes for $f(\xi, r) = 0$ were determined graphically. This distance ξ and radii r values, obtained as a result of calculation for four hammers in Fig. 3, were compared with real articulation hole radii and the distances presented in Fig. 3. Compliance with the condition of the centre of percussion (1) at the end points of the hammers was evaluated.



a) b) c) d)

Fig. 3. **Different size rectangular style manufactured hammers**

Results and discussion

The results of calculation the compliance of the hammer 110x50 mm (Fig. 3 a) sizes with the condition in the equation (1) are shown in Fig. 4 and Fig. 5. The function *f*(ξ, *r*) = 0 value is for the distance ξ = 35 mm and articulation hole radius *r* = 11 mm. The manufactured hammer sizes are ξ = 32 mm and *r* = 10 mm. The difference is 8.6 % for the distance ξ and 9 % for the radius *r*. These differences are less than 10 % and other constructive observations may be made. It can be concluded that the calculated articulation hole distance from the end of the hammer in Fig. 3 a is close to one third of the hammer length – 36.7 mm (for ξ = 32 mm – incongruity only less 5 %) as the distance of the impact centre for monolithic plate.

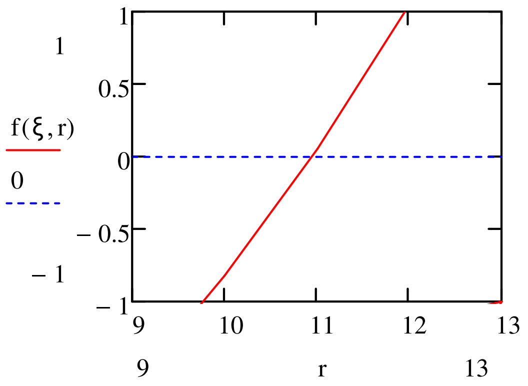


Fig. 4. **Function *f*(ξ, *r*) (mm) in dependence on radius r (mm)**

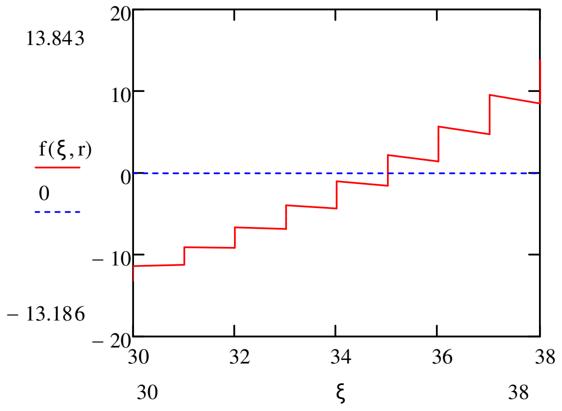


Fig. 5. **Function *f*(ξ, *r*) (mm) in dependence on distance ξ, (mm)**

The results of calculation compliance of the hammer 285x60 mm (Fig. 3 b) sizes with the condition in the equation (1) are shown in Fig. 6 and Fig. 7. The function *f*(ξ, *r*) = 0 value is for the distance ξ = 93 mm and the articulation hole radius *r* = 13 mm. The manufactured hammer sizes are ξ = 35 mm and r = 10.5 mm. The difference is 62 % for the distance ξ and 12 % for the radius *r*. These differences are very sufficient and may be caused without observations about the percussion centre at the end of the hammer during design. It can be concluded that the manufactured articulation hole distance from the end of the hammer in Fig. 3 b is far from one third of the hammer length – 95 mm (for ξ = 35 – incongruity 63 %) as the distance of the impact centre for monolithic plate.

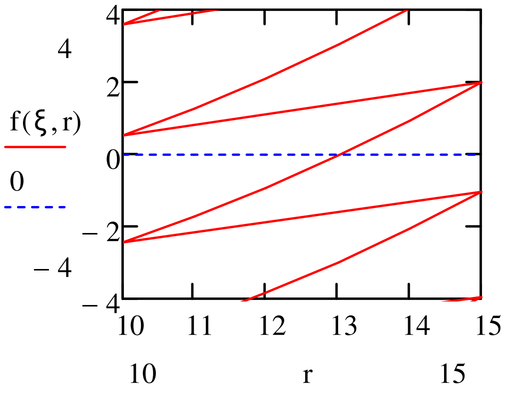


Fig. 6. **Function *f*(ξ, *r*) (mm) in dependence on radius *r*, (mm)**

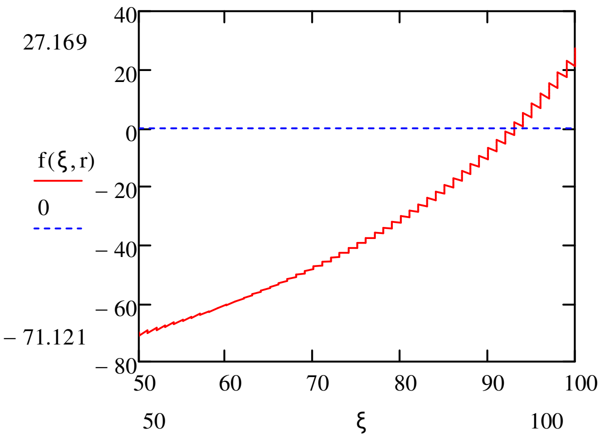


Fig. 7. **Function *f*(ξ, *r*) (mm) in dependence on distance ξ, (mm)**

The results of calculation compliance of the hammer 225x50 mm (Fig. 3 c) sizes with the condition in the equation (1) are shown in Fig. 8 and Fig. 9. The function *f*(ξ, *r*) = 0 value is for the distance ξ = 72 mm and the articulation hole radius *r* = 11.9 mm. The manufactured hammer sizes are

ξ = 35 mm and r = 10 mm. The difference is 51 % for the distance ξ and 16 % for the radius r. These differences also are very sufficient and may be caused without observations about the percussion centre at the end of the hammer during design. It can be concluded that the manufactured articulation hole distance from the end of the hammer in Fig. 3 c is far from one third of the hammer length – 75 mm (for 35 mm – incongruity 53 %) as the distance of the impact centre for monolithic plate.

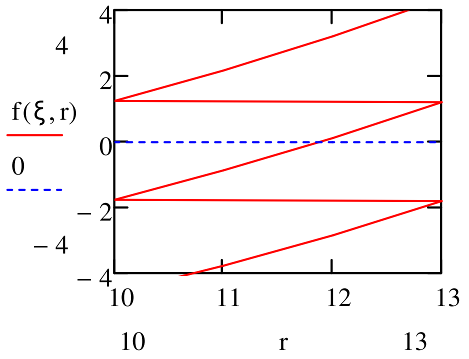


Fig. 8. **Function $f(\xi, r)$ (mm) in dependence on radius r, (mm)**

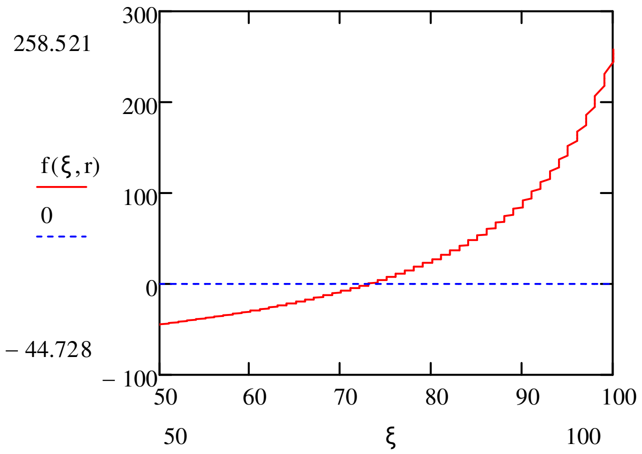


Fig. 9. **Function $f(\xi, r)$ (mm) in dependence on distance ξ, (mm)**

The results of calculation compliance of the hammer 225x50 mm (Fig. 3 d) sizes with the condition in the equation (1) are shown in Fig. 10 and Fig. 11. The function $f(\xi, r) = 0$ value is for the distance ξ = 40 mm and the articulation hole radius r = 7.5 mm. The manufactured hammer sizes are ξ = 20 mm and r = 9 mm. The difference is 50 % for the distance ξ and 20 % for the radius r. These differences also are very sufficient and may be caused without observations about the percussion centre at the end of the hammer during design. It can be concluded that the manufactured articulation hole distance from the end of the hammer in Fig. 3 d is far from one third of the hammer length – 40 mm (for ξ = 20 mm – incongruity 50 %) as the distance of the impact centre for monolithic plate.

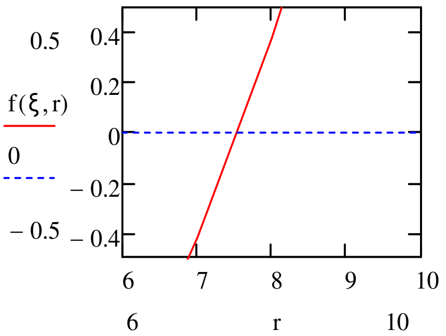


Fig. 10. **Function $f(\xi, r)$ (mm) in dependence on radius r, (mm)**

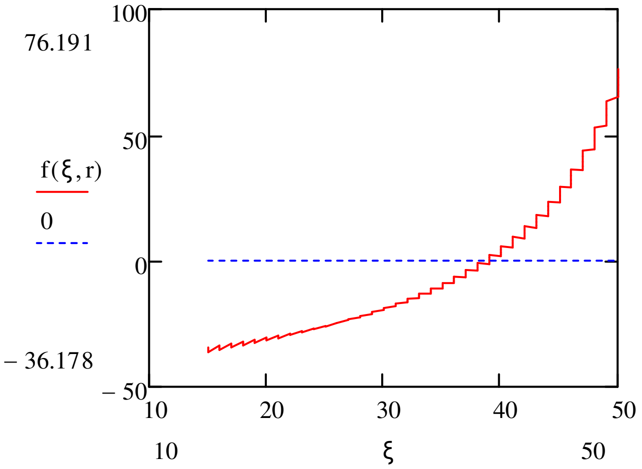


Fig. 11. **Function $f(\xi, r)$ (mm) in dependence on distance ξ, (mm)**

Conclusions

1. The results of calculation compliance of four sizes of manufactured hammers with condition of center of percussion at the end point of the hammer show that only hammer 110x50 mm

sizes partly satisfies this condition. The difference between calculated and manufactured values are 8.6 % for articulation hole distance from end point of hammer ξ and 9 % for it radius r.

2. For hammer 110x50 mm calculated articulation hole distance from the end of the hammer is close to one third of hammer length – 36.7 mm (for $\xi = 32$ mm – incongruity only less 5 %) as distance of impact center for monolithic plate.
3. The difference between calculated and manufactured values for articulation hole distance from end point of other (sizes 285x60, 225x50 and 120x40) three hammers (62 %, 51 % and 50 %) are very sufficient and may be caused without design observations about percussion center at the end of hammer during design.
4. The difference between calculated and manufactured values for articulation hole radii for all four hammers (9 %, 12 %, 16 % and 20 %) are not very sufficient and may be caused by other constructive observations (for example due to the pivot pin material selection).
5. The hammer mill hammer design so that interaction between the hammer and material occur at percussion center of hammer is actual. Implementing this condition the percussions in the articulation may be eliminated and so the machine service life is extended.

References

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