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THE RELATIONSHIP BETWEEN THE MASS OF THE HARVESTER HEAD AND ITS MAXIMUM CUTTING DIAMETER

Summary

The aim of the study was to demonstrate a relationship between the type/mass of harvester heads and their maximum cutting diameter. The study evaluated heads for felling, delimbing, and bucking trees, mounted on an extensible boom, with a chain saw and feed rollers, designed principally for coniferous stands. The heads included in the study were mostly products of European manufacturers: AFM, CTL, Kesla, Keto, Komatsu, Konrad, Logmax, Logset, Moipu, Ponsse, Rottne, Silvatec, SP Maskiner, and Viking. The analysis was based on technical specifications provided by the producers. The results were analyzed statistically by ANOVA and T-Tukey's multiple confidence intervals at the level of significance α=0.05. The trend lines were fitted by the method of least squares. The slopes of linear regression lines representing the mass of harvester heads by particular manufacturers as a function of their maximum cutting diameter differ considerably from one producer to another: 22.5 for Logset, 22.5 for Ponsse, 30.4 for Keto, 33.9 for Kesla, 40.7 for SP Maskiner, 57.1 for Logmax, 66.5 for Komatsu, and 78.2 for AFM. Keto Forst Ecolit weighing 297 kg, designed for felling the thinnest trees (of up to 30 cm in diameter) is the lightest European harvester head with feed rollers and a chain saw. By contrast, Keto 825TS, weighing 2450 kg is the lightest head capable of felling, delimbing, and bucking the thickest trees (of up to 102 cm in diameter). Heads for final felling and thinning with a maximum cutting diameter of 60-70 cm have the largest percentage (31.5%) in European harvester heads offered on the market. The smallest percentage (5.6%) is noted for thinning heads with a maximum cutting diameter of up to 40 cm. There is a positive correlation between the mass of harvester heads and their maximum cutting diameter. Harvester heads designed for felling or for felling and thinning are statistically heavier than smaller types of heads. There is, however, no statistically significant difference in mass between heads for thinning and heads for thinning and felling. A head by the same manufacturer, with a maximum cutting diameter greater by 10 cm, is heavier by 225-782 kg, depending on the manufacturer.
Key words*: timber harvesting, multi-operational, logging machines, European market, pine harvesting*

MASA GŁOWICY HARWESTEROWEJ A JEJ MAKSYMALNA ŚREDNICA CIĘCIA

Streszczenie

Celem pracy było wykazanie zależności między typem/masą głowicy harwesterowej a jej przydatnością do pozyskiwania drewna w różnych grupach wymiarowych drzew. Ocenie poddano głowice ścinkowo-okrzesująco-przerzynające, przeznaczone do mocowania wysięgnikowego, wyposażone w piłę łańcuchową oraz rolki napędowe, przeznaczone głównie do pozyskiwania drewna w drzewostanach iglastych. Badaniami objęto głowice producentów europejskich: AFM, CTL, Kesla, Keto, Komatsu, Konrad, Logmax, Logset, Moipu, Ponsse, Rottne, Silvatec, SP Maskiner i Viking. Analizę przeprowadzono na podstawie danych technicznych przedstawionych przez oferentów. Uzyskane wyniki poddano analizie statystycznej przy wykorzystaniu metody analizy wariancji i wielokrotnych przedziałów ufności T-Tukeya, przy założonym poziomie istotności α=0,05. Linie trendu dopasowano metodą najmniejszych kwadratów. Współczynnik kątowy prostych regresji, wyznaczonych dla ich masy w funkcji ich maksymalnej średnicy cięcia, dla głowic każdego producenta jest inny i wynosi: Logset – 22,5, Ponsse – 22,5, Keto – 30,4, Kesla – 33,9, SP Maskiner – 40,7, Logmax – 57,1 i Komatsu – 66,5, AFM – 78,2. Najlżejszą produkowaną w Europie głowicą rolkową wyposażoną w piłę łańcuchową jest Keto Forst Ecolit o masie 297 kg, która przeznaczona jest do ścinania najcieńszych drzew (o średnicy do 30 cm). Z kolei najlżejszą głowicą umożliwiającą ścinkę, okrzesanie i przerzynkę najgrubszych drzew (o średnicy do 102 cm) jest Keto 825TS o masie 2450 kg. Głowice zrębowo-trzebieżowe (o maksymalnej średnicy ścinki z przedziału 60-70 cm) stanowią największy udział (31,5%) wśród europejskich głowic harwesterowych. Najmniejszy udział w rynku (5,6%) obejmują głowice trzebieżowe (o maksymalnej średnicy ścinki do 40 cm). Istnieje dodatnia korelacja między masą głowicy harwesterowej a jej średnicą cięcia, a także głowice zrębowe i zrębowo-trzebieżowe swoją masą odbiegają statystyczne od mniejszych typów głowic. Natomiast brak statystycznej różnicy w masie pomiędzy głowicami trzebieżowymi i trzebieżowo-zrębowymi. Zamiana głowicy na głowicę tej samej firmy, ale o większej o 10 cm maksymalnej średnicy ścinki skutkuje zwiększeniem jej masy, zależnie od producenta, o 225-782 kg.
Słowa kluczowe*: pozyskiwanie drewna, maszyny wielooperacyjne; rynek europejski, pozyskiwanie sosny*

1. Introduction

Increasingly common in Poland, mechanized wood harvesting is more efficient and often cheaper than the use of a handheld chainsaw [11, 15, 22, 35]. Nevertheless, new techniques and technologies implemented in the mechanized harvesting of wood [20] are evaluated not only in terms of their cost and efficiency [3, 21, 26, 29, 32], but also in terms of dangers that they pose for the forest environment [17, 29], including the potential damage to the forest floor trampled by tree felling and hauling vehicles [4, 5, 13, 23]. In the case of multipurpose forest machines, such damage is also related to the considerable mass of the harvester head [22, 28, 36].

Currently available heads are designed for work with various base vehicles: wood harvesters, excavators, farm tractors, or others [10, 34], and equipped with cutting modules based on shears [18, 19], chain saws, or circular saws [6, 7, 8]. Some models are also designed specifically for wood harvesting on fuelwood plantations [18, 19, 22].

The aim of the study was to demonstrate a relationship between the type/mass of harvester heads and their maximum cutting diameter.

2. Material and methods

The study evaluated heads for felling, delimbing, and bucking trees, mounted on an extensible boom, with a chain saw and feed rollers, designed principally for coniferous stands. The study evaluated products of fourteen European manufacturers: AFM, Kesla, Keto, Logset, Moipu, and Ponsse of Finland, Logmax, Rottne, SP Maskiner, and Viking of Sweden, CTL of Germany, Konrad of Austria, Silvatec of France, and heads manufactured by the multinational Komatsu group.

The study included all models of harvester heads offered by the above companies. The analysis was based on technical specifications provided by producers.

The heads were divided into the following categories, depending on the primary purpose of the head: heads for thinning (with a maximum cutting diameter of up to 40 cm), heads for thinning and felling (with a maximum cutting diameter of 40-60 cm), heads for felling and thinning (with a maximum cutting diameter of 60-70 cm), and heads for felling (with a maximum cutting diameter of more than 70 cm) [31]. Since the thinning and felling group included over twice as many models as any other, it was additionally split into two subgroups with maximum cutting diameters of 40-50 cm and 50-60 cm.

Trend line analysis included only heads by producers offering at least five different models. Trend lines were fitted by the method of least squares by Microsoft Excel software.

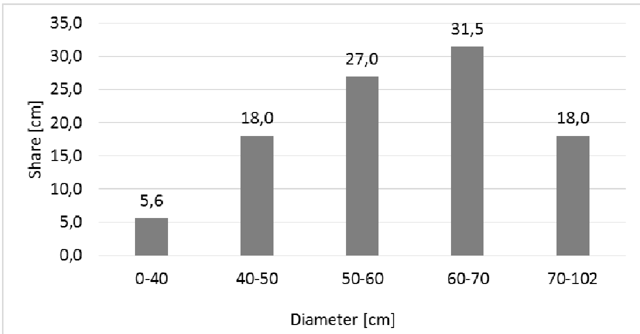
The results were analyzed statistically by ANOVA and T-Tukey's multiple confidence intervals at the level of significance α=0.05, using a Statistica 12 PL software package.

3. Results

The smallest percentage (5.6%) of European harvester heads offered on the market are thinning heads, since only 5 models are available, all manufactured by Keto. The largest percentage (45.0%) are heads for thinning and felling (40 models), among which most have a maximum cutting diameter of 50-60 cm (27.0%). Among the groups of heads differing by no more than 10 cm in their maximum cutting diameter, the most numerous is the group of heads for final felling and thinning (28 models, 31.5%)

The mass of harvester heads is positively correlated with their maximum cutting diameter (Figs. 2 and 3). However, the slopes of linear regression lines representing the mass of harvester heads as a function of their maximum cutting diameter are different for each manufacturer. The slope is the smallest for heads by Logset, amounting to 22.5, which means that a Logset head with a maximum cutting diameter greater by 10 cm, is heavier by 225 kg.

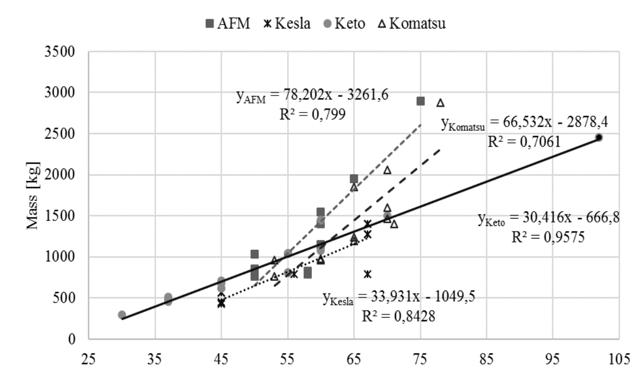
Thus the mass of the Logset heads increases the least with the increase in their maximum cutting diameter. In contrast, the smallest percentage (5.6%) of European harvester heads offered on the market includes thinning heads, since only 5 models are available, all manufactured by Keto. The largest percentage (45.0%) is noted in case of heads for thinning and felling (40 models), among which most have a maximum cutting diameter of 50-60 cm (27.0%). Among the groups of heads differing by no more than 10 cm in their maximum cutting diameter, the group of heads for final felling and thinning (28 models, 31.5%) is the most numerous.



Source: own work / Źródło: opracowanie własne

Fig. 1. The percentage of particular types of harvester heads (defined by their maximum cutting diameter) offered by European manufacturers

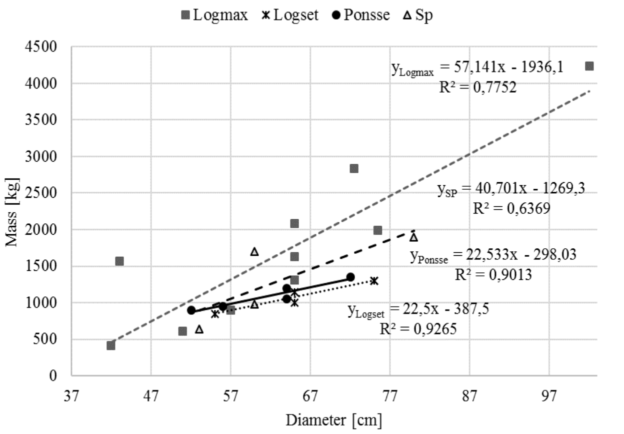
Rys. 1. Procentowy udział poszczególnych typów głowic harwesterowch (determinowanych ich średnicą cięcia) oferowanych przez producentów europejskich



Source: own work / Źródło: opracowanie własne

Fig. 2. The mass of harvester heads as a function of their maximum cutting diameter (for models by AFM, Kesla, Keto and Komatsu)

Rys. 2. Masa głowic harwesterowych w funkcji ich maksymalnej średnicy cięcia (modele firm AFM, Kesla, Keto i Komatsu)



Source: own work / Źródło: opracowanie własne

Fig. 3. The mass of harvester heads as a function of their maximum cutting diameter (for head models by Logmax, Logset, Ponsse and SP)

Rys. 3. Masa głowic harwesterowych w funkcji ich maksymalnej średnicy cięcia (modele firm Logmax, Logset, Ponsse i SP)

The mass of harvester heads is positively correlated with their maximum cutting diameter (Figs. 2 and 3). However, the slopes of linear regression lines representing the mass of harvester heads as a function of their maximum cutting diameter are different for each manufacturer. The slope is the smallest for heads by Logset, amounting to 22.5, which means that a Logset head with a maximum cutting diameter greater by 10 cm, is heavier by 225 kg.

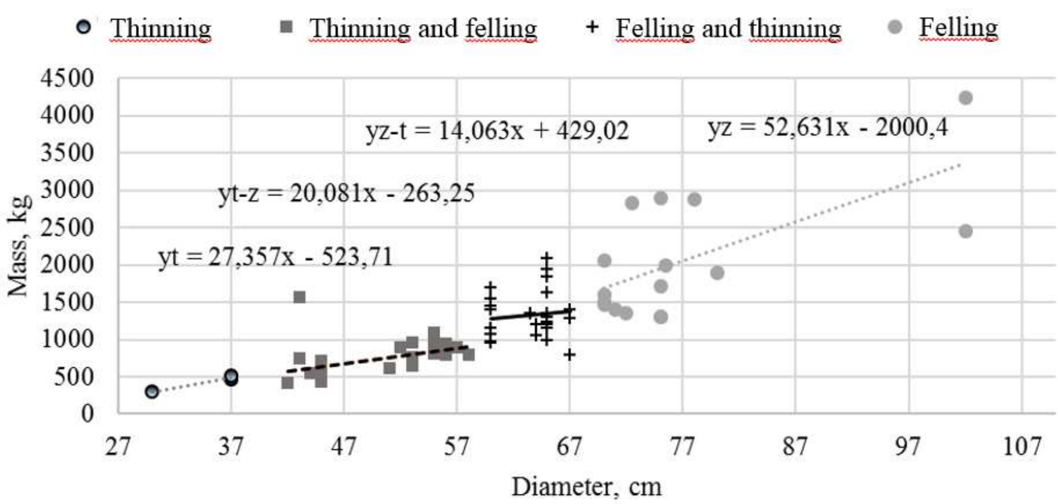
Thus the mass of the Logset heads increases the least with the increase in their maximum cutting diameter. In contrast, the largest slope was found for AFM heads, for which a 10 cm increase in the maximum cutting diameter is associated with an increase in the mass of the head by as much as 782 kg, which is almost 3.5 times as much as for Logset heads. The same increase in the maximum cutting diameter of the head is associated with an increase in its mass by 225 kg for Ponsse heads, 304 kg for Keto, 339 kg for Kesla, 407 kg for SP Maskiner, 571 kg for Logmax, and 665 kg for Komatsu.

The broadest range of heads in terms of the maximum cutting diameter is offered by Keto with 17 models (30-102 cm) and by Logmax with 11 models (42-102 cm). With regard to other companies, 12 models are manufactured by both Kesla (45-67 cm) and Komatsu (53-78 cm), 10 by AFM (45-75 cm), 5 by both Logset (50-75 cm) and Ponsse (52-72 cm), 4 by SP Maskiner (53-80 cm), 3 by Konrad (55-75 cm), Rottne (45-50 cm) and Silvatec (35-64 cm) each, and 2 by both CTL (43 cm and 53 cm) and Moipu (44 cm and 55 cm). Keto Forst Ecolit weighing 297 kg, designed for felling the thinnest trees of up to 30 cm in diameter is the lightest European harvester head with feed rollers and a chain saw. By contrast, Keto 825TS, weighing 2450 kg is the lightest head capable of felling, delimbing, and bucking the thickest trees (of up to 102 cm in diameter). Logmax 12000XT, designed for the same purpose, is almost twice as heavy: 4234 kg.

The trend lines for particular types of harvester heads are also linear (Fig. 4). The slope of the linear regression line is the smallest (14.1) in the case of heads for final felling and thinning, in which a 10 cm increase in the maximum cutting diameter is combined with a 141 kg increase in mass. The corresponding mass increase amounts to 201 kg in the case of heads designed for thinning and felling, 274 kg in the case of heads for thinning, and 526 kg in the case of those for felling.

The analysis of variance (Fig. 5) revealed that the thinning heads did not differ significantly in terms of mass from those designed for thinning and felling. The felling heads, on the other hand, were significantly heavier than any other type. Likewise, the heads for felling and thinning differed significantly from all other types of heads in terms of their mass.

The dispersion of this characteristic was low among the heads for thinning and those for thinning and felling. It was, however, significantly higher for the heads for felling and thinning, and the highest for the felling heads, which demonstrates considerable differences in mass among particular models of the same type manufactured by different producers.



Source: own work / Źródło: opracowanie własne

Fig. 4. The mass of harvester heads as a function of their use/type (i.e. their use)

Rys. 4. Masa głowic harwesterowych w funkcji jej maksymalnej średnicy cięcia/typu (przeznaczenia głowicy)

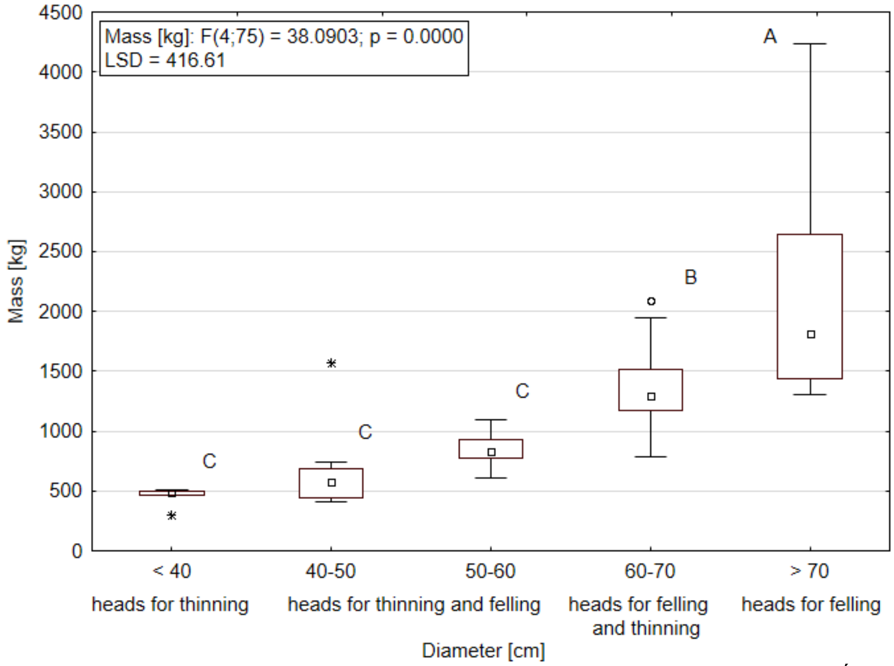


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Fig. 5. The distribution of the head mass for heads of different use/type and the maximum cutting diameter: * A, B, C – differences between the results with these indices are statistically significant

*Rys. 5. Rozkład masy głowic w funkcji jej typu (przeznaczenia głowicy) i maksymalnej średnicy cięcia: * A, B, C – oznacza statystyczną różnicę miedzy wynikami oznaczonymi różnymi indeksami*

4. Discussion

The mass of John Deere harvester heads manufactured by Waratah for the United States market corresponds to the average European level. The slope of the trend line representing the mass of these heads as a function of their maximum cutting diameter equals 45.5 [2], whereas the average for European heads amounts to 44.0.

Single-purpose heads with a circular saw are much heavier than multipurpose harvester heads. Quadco 20C, weighing 2268 kg [9] are the lightest circular-saw heads with a maximum cutting diameter of 50.8 cm, and John Deere FD45, weighing 2200 kg. The mass of a harvester head with an identical maximum cutting diameter is less than one-third of those: 610 kg (Logmax 4000B). For circular-saw heads, mass as a function of the maximum cutting diameter increases faster than for harvester heads. In the case of heads with a maximum cutting diameter of 62 cm, the single-purpose John Deere FR24B weighs 3946 kg [9], whereas the harvester head Komatsu 350.1 is less than one-fourth of that weight: 960 kg.

Heavier heads cannot be used on a long boom, unless mounted on a heavier base vehicle [2]. Obviously, light heads and smaller base vehicles cause less damage to the remaining stand and exert less pressure on the soil [14].

The duration of the felling process is positively correlated with the diameter of the trees being felled [16, 27], but there is no statistically significant difference in the efficiency of harvesting wood with light and heavy harvester heads. Therefore, a small harvester equipped with a light head can achieve the same efficiency as a large harvester with a heavy head [14]. Differences in efficiency may result from different harvesting techniques. With harvester heads used on a strip road, efficiency can be improved (by 59%) by placing trees in the middle of the road rather than along the roadside [32].

Producers continue to improve harvester heads by redesigning both their mechanical and hydraulic systems so as to reduce their mass and increase their operating efficiency [1]. For example, in the case of heads by Ponsse and Valmet (currently Kamatsu), the slope representing the change in their mass decreased, respectively, from 33.1 to 22.5 and from 59.2 to 22.5 [2]. Moreover, attempts are being made to equip harvester heads with new measuring devices using 3D scanners, in order to gauge the diameter and length of trees with greater accuracy [25]. Programs for controlling the operation of harvester heads are also being improved [33]. In addition, studies have been conducted on the possibility of using harvester heads in deciduous stands. CTL 40HW heads have been successfully used for oak harvesting [24, 30].

5. Conclusions

- The largest percentage (31.5%) among the European harvester heads examined in this study is noted in case of heads for final felling and thinning with a maximum cutting diameter of 60-70 cm The smallest percentage (5.6%) includes thinning heads with a maximum cutting diameter of up to 40 cm
- There is a positive correlation between the mass of harvester heads and their maximum cutting diameter. Harvester heads designed for felling or for felling and thinning are statistically heavier than smaller types of heads There is, however, no statistically significant difference in mass between heads for thinning and heads for thinning and felling
- A head by the same manufacturer, with a maximum cutting diameter greater by 10 cm, is heavier by 225-782 kg, depending on the manufacturer.

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