DESIGN OF FOREST TREES CUTTING MECHANISM

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Abstract
In spite of mechanized harvesting methods of the poplar trees in the world, the method of felling and harvesting them in Iran is however carried out manually and is still in rudimentary stages and has not been mechanized yet. Considering the technical and scientific advancement of the harvesting and processing tools in industrial countries and also the significance of the wood in the modern human life, and importance of poplar trees, the design of this mechanisms were carried out in a research work which is presented in this paper. These mechanisms include the cutting system for cutting and felling of green forest tree branches to work mostly hydraulically. The maximum weight that a tree may have, has been experimentally determined. The forces required to cut branches have also been determined with the help of experimental data and initial dimensional information. The geometric shape of cutting blades has been designed to have optimum efficiency and high quality of the cutting operations. The simplicity and ease of manufacturing and assembling the parts indigenously were kept in mind during the design process. The whole system is an advanced tool in afforestation and modern poplar tree cutting and processing.

Key words: Forest trees, Cutting mechanism, Fixed blade, Movable blades

INTRODUCTION
Forest exploitation is a kind of poplar trees wood harvesting which is to be done according to scientific and technical procedures, while observing the social and economical principles. The most important point to bear in mind is the forest sustainability in this case. This means that the harvesting of the forest trees can be achieved with the help of appropriate technology, preserving the forest and using the forest wood at the same time. The availability of appropriate technology also facilitates the forest ecosystem management. In spite of mechanized harvesting methods of the poplar trees in the world (1), the method of felling and harvesting them in Iran is carried out manually and is still in rudimentary stages. The machinery extension in the forest is due to industrial development, better machine performance, expediting doing job, human willingness to do the work with machine and economical reasons. With the help of modern machines, the trees are initially fallen, and then processed. Delimbing or debranching, topping and bucking are to be performed successively (2).

A tree harvesting machine is composed of several parts. The most important part for cutting the tree in the modern machine is either rolling harvesting head or single grip harvesting head (3 and 4), although the other parts of the complete machine is also required. These parts are skidding, loading, gripping, feeding and transporting units (5). Various types of forest trees harvesting heads have also been designed and developed so far which are used in different countries in the world (6 and 7). Some special machines for delimbing or debranching have also been designed and developed (8, 9, 10 and 11).

Considering the technical and scientific advancement of the harvesting and processing tools in industrial countries and the significance of wood in modern human life and the importance of scientific design and development of forest trees processing mechanisms and...
manufacturing methods for the Iranian forest trees activities, a research work was conducted which is the subject matter of the present paper (12).

DESIGN METHODOLOGY

The cutting mechanism is an important part of the harvester head. This mechanism is comprised of movable and fixed cutting blades which are to be designed for the future manufacture and development. The duty of the cutting blades is to cut the tree branches on the commencement of operation and cutting the trunks in equal sections or bucking during the cutting operation. The delimbing system is the fundamental part of the processing head and its duty is to cut the branches on the tree trunk. As mentioned there is two types of blades, the movable blades which are mounted on movable jaws and fixed blade which is fixed on a stand and is mounted on the processing head chassis. Figure 1 shows the position and approximate configuration of the movable and fixed blades. The movable blades are mounted on movable Jaws 1 and 2. The movable blades 1 and 2 and fixed blade 3 form a closed medium. The tree trunks pass through this medium and the branches are therefore cut by the blade edge of this closed medium. A1 and A2 are the stands.

For high performance of delimbing system and high quality of harvested tree trunks, which are debranched by this system, the internal curvature of the closed medium must conform to the curvature of the lateral surface of the tree trunk with various diameters. In other words the distance of internal surface of the trees with different diameter should be minimal. Specialists indicate the variation of tree diameters to be cut is ranging from 15 cm to 30 cm. The geometry of most of the blades is semicircular for high quality harvested trunks against the V-shape blades.

The main aim in designing the cutting mechanism is to design a system in which the distance between the external surface of the trunk and the internal surface profile of the blade in the trunks with various diameters is maintained minimum and the blades curvature profile or the internal surface of the jaws holding the blade greatly conforms to the trunk external surface curvature. Figure 2 shows a proposed configuration for the assumed mechanism.

Fig. 1: A schematic representation of the delimbing system.
In figure(2) assuming $C_1$ is the cross section of the tree trunk with maximum diameter and the lines $ABC$ and $ADC$ are considered to represent the movable blades of the mechanism. The line $X-X'$ represents the fixed blade. The circle $C_2$ with diameter half of that of $C_1$ represents the tree trunk cross section with minimum diameter. The circle $C_3$ is chosen in order to design the hinge for the jaw such that it is tangent to the sides $AB$ and $BC$. Then the bisecting line to the line connecting the $C_2$ and $C_3$ origin is also drawn. Any point on this bisecting line can be a center for the hinge of the Jaw $ABC$. To have a least distance between the jaw of circle $3$ (minimum tree trunk diameter) at point $B$, a portion of the blade between touching points $T_3$ and $T_4$ are omitted and instead of that, arc $T_3T_4$ from circle $C_3$ is considered (fig.2). The same procedure is used for the end portion of the blade and here also the arc $T_1T_2$ from the circle $C_1$ is considered to be a portion of the blade, though this portion has no use while gripping the smaller diameter trunks and is used only for the trunks with larger diameters. Figure 3 shows the configuration geometry of the movable jaw based on the minimum and maximum tree trunk diameters.

Fig.3 : A schematic representation of the configuration geometry of the movable blade jaw.
It can be seen from figure (3) that a portion of the blade from $T_5$ to $T_4$ is straight, from $T_4$ to $T_3$ is an arc from circle $C_3$ equal to about 90 degrees, from $T_3$ to $T_2$ is again straight, and from $T_2$ to $T_1$ is also an arc from circle $C_1$ and is equal to about 45 degrees. This configuration should be pursued exactly to build the blade and its jaw. The other jaw is symmetric to this jaw.

Figure 4 shows the gripping state of the assumed blade with respect to 3 circles with maximum, medium and minimum size, everyone is representative of a tree trunk with maximum, medium and minimum diameter with assumption that the revolving center for the jaw is point $T_5$.

The position to mount the fixed blade on the head chassis is somewhat before the movable blades so that the branches which cannot be cut by the movable blades are cut by the fixed blade. A portion of the trunk comes in contact with the parallel line to the straight line $X-X^1$ passing through the point $T_5$ in figures (2 and 3) its branches are therefore cut by fixed blade.

A fixed blade starting from point $T_5$ parallel to line $X-X^1$ just touching the line $AD$ is to be designed in this case. The radius of the curvature of the blade is equal to the radius of the curvature of the circle $C_1$ in figure (2). Figure 5 shows the geometry of such a fixed blade. The blade is extended from both sides with an arc equal to 10 degrees to have a suitable overlap.

Fig.4: The gripping state of the blade with respect to tree trunk size.

Fig.5: Schematic representation of the configuration geometry of fixed blade.
THE DESIGN REQUIREMENTS

The design requirements are concerned with the forest tree specifications. The tree specifications are crucial in the quantitative analysis of the movable and fixed blade dimensions. For this purpose, some experiments were performed to calculate the forest tree specifications needed for the design requirements. The results of an experiment is shown in table(1). Since the maximum and minimum tree trunk diameter is 30 cm and 15 cm for designing the cutting mechanism, therefore the other tree parameters such as weight, useful trunk length and the total tree length can be related and obtained approximately.

THE DESIGN RESULTS

A graphical methodology was followed to obtain the initial configuration of the cutting mechanism. This methodology resulted in obtaining the exact shape of the movable blades and fixed blade which are shown in figures(1-5). A field experiment was carried out to find the spruce tree specification, the result of which is given in table(1). Using a drawn geometric configuration of the cutting blades and the experimentally determined tree specifications, the force analysis of this parts was performed with the help of mathematical relationships, the result of which is out of the scope of this paper. The combined graphical representation of the cutting parts and using the result of the field experiments resulted in the cutting parts exact dimensions determination. Figure 6 (a and b) shows the left arm of the cutting mechanism along with the dimensions (part a), and the final shape of the cutting mechanism Jaws(part b).

These parts are manufactured and assembled indigenously. The total cutting mechanism is an advanced tool in forest tree management and tree processing including cutting.

(a)

(b)
Fig. 6: (a) The dimensions of delimbing blades, and (b) Final shape of cutting blades.

Table 1: The spruce tree specifications.

<table>
<thead>
<tr>
<th>Tree parameters</th>
<th>Tree No</th>
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<tr>
<td></td>
<td>1</td>
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<tr>
<td>Useful tree length (m)</td>
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<td>Tree weight for the useful length (kg)</td>
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<td>Weight of branches and leaves (kg)</td>
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<td>The total weight (kg)</td>
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<td>The maximum diameter (cm)</td>
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<td>The minimum diameter (cm)</td>
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<td>The average trunk density (kg/m³)</td>
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</table>

REFERENCES