Research on Security of Improved Design of Knapsack Brush Cutter

Bo Li , Shusen Li

College of Mechanical and Electrical Engineering
Northeast Forestry University
Haerbin City, China

***Abstract* — Knapsack brush cutter is a kind of portable forestry machinery which is widely used at home and abroad. It was mainly used in forestry operation field such as landscaping, garden maintenance, forest cleaning, forest tending and harvesting crops. Chronic occupation injury and safety accidents caused by cutting irrigation operation ever are increasing in China. Worker's wrong cutting irrigation posture is the main cause of workers' occupational diseases and hazards. Based on ergonomics, the redesign of shape and structure of brush cutter can standard the postures of operators, thereby reducing the disease rate of the operators' musculoskeletal disorders and it can reduce the occupational safety accidents.**

Keywords- Knapsack Brush Cutter: Improved Design; Cutting Irrigation; Ergonomics.

I. INTRODUCTION

Brush cutter is a kind of portable forestry machinery widely used at home and abroad. It mainly used in forestry operation field such as landscaping, garden maintenance, forest cleaning, forest tending and harvesting crops. It is powered by a small gasoline engine. It completes all kinds of cutting task through the rotating blades droved by the transmission shaft. With the advantages of multifunction, light weight, convenient transfer, high available and simple installation, the brush cutter could reduce the labor intensity, improve the efficiency and ensure the quality of the work[1-3]. Because of the constrains from the work task and the environment, the operation of the brush cutters have to rely on the hand grip and operation. The noise, vibration, and scraps made by the brush cutter might cause the accidents and lead to the occupational safety problems. Luke D. Knibbs, Tint P and other Australian scholars study on the occupational healthy risks caused by the vibration and noise of the brush cutters[4-5]. The scholars from Northeast Forestry University Li Bo and Li Shusen studied on the relationship between the posture of the operation and the professional diseases of the muscles and bones[6-7]. Dong Jinbao and Li Wenbin ,the scholars from Peking Forestry University, devoted themselves to the noise and vibration of brush cutters[8]. However, there is no intense research for how to improve the design of the structure and modeling, how to cut down the labor intensity and how to avoid the accidents in domestic. Therefore, it has practical significance to improve the design of the brush cutters through analyzing the reason for occupational injury of the brush cutters.

II. THE OCCUPATIONAL INJURY CAUSED BY THE BRUSH CUTTER OPERATION

In China, the main users of the brush cutters are forestry workers, gardeners and peasants[3]. Forestry workers and gardeners use brush cutter to remove weeds, trim the shrubs, do forestry tending and greening work while peasants use brush cutter to cut the pastures and other crops. The forestry workers and gardeners will be subject to certain hours of trainings before operation, which can avoid some occupation injuries. But because the outsourcing management system of forestry and garden sector, there is also a part of temporary workers failed to effectively receive trainings. In addition, because the brush cutter entered the national agricultural subsidies directory[9], more and more farmers began to use brush cutter for agricultural production. The rusty skills and the fatigues of long time working caused the frequent occupational injuries.

The occupational harm of the brush cutter is mainly divided into two types:

(1)Chronic occupation injury

The chronic occupational injuries due to the brush cutters include the musculoskeletal diseases of back, neck and shoulder caused by the poor posture; the upper limb paralysis, the carpal tunnel syndrome and the occupation Reynaud's phenomenon caused by the vibration and the tinnitus, the hearing loss and the distraction caused by the noise.

(2)Safety accidents

The safety accidents include the imbalance of the body and the tumbles cause by the weight of the machine and the fatigue; the accidents caused by the splashes; the injuries of the blades and branches caused by the fatigue and carelessness etc.

III. THE ANALYSIS OF THE OCCUPATIONAL INJURY CAUSED BY THE BRUSH CUTTER OPERATION

Slappended proposed the theory of precipitating and influencing factors of accidents, in 1993[10], which considered the origin of the accidents was the relationship between each parts in the system. As shown in Fig.1, the factors such as operator characteristics, work characteristics and equipment characteristics are closely related to the operation and they are the direct factors result in the accidents. The psychology, society and environment factors effect the safety deeply but have no direct relationship.

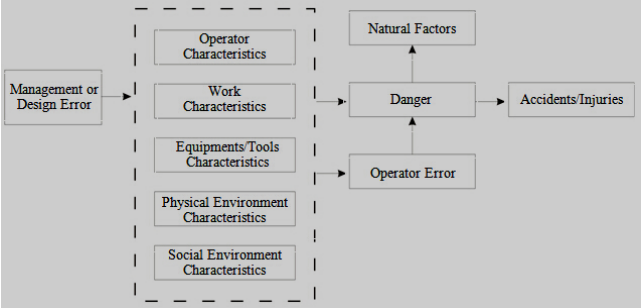

Figure.1. The theory of precipitating and influencing factors of accidents

According to the theory proposed by Slappended, the factors caused the occupational injuries could be divided into following two aspects.

(1)Human factors

The safety accidents caused by the human factors can be summarized as follows:

The chronic occupational disease caused by the poor postures such as, neck and shoulder pain, back pain, visual fatigue, tinnitus and hand paralysis;

The body imbalance, dumping, tripping, lateral fall and other accidents caused by the operating fatigue and attention lax;

The operator errors caused by personal qualities such as too much pressure and rusty operating skills.

(2)Objective factors

Lots of brush cutter accidents are caused due to objective factors such as design issues and environment issues. For example, the load is so large that causes operators physiological fatigue, and the surface is not flat lead to the operators out of balance. This paper mainly discusses the design issues of the brush cutters affecting the occupational injuries. There are following points:

Not ergonomic back cushion shapes, handle size, working rod length and other design factors caused the healthy accidents;

The hard objects spatter formed during the operating process harm to human body;

The influence of vibration and noise to human mind and body.

IV. The Research on Brush Cutter Safety Improvement Design

According to the front part, the design issues of brush cutters might bring occupational injuries and safety accidents to operators. It is necessary to improve the operational safety through the improvement design of brush cutters. This paper study on improvement design of the knapsack brush cutter which widely used in China. The body consists of three parts: engine, hose and the main connecting parts. The body, fuel tank, clutch and the hose connection parts are shown in Fig2 to Fig 4.

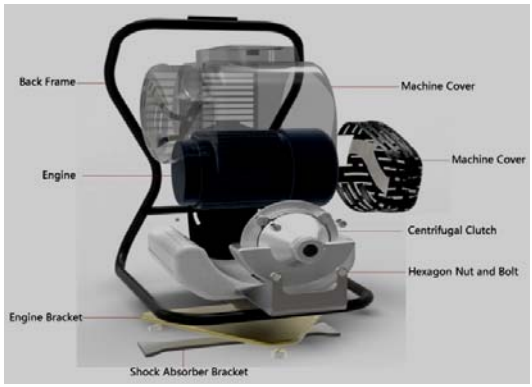

Figure. 2. The Body of the Brush Cutter

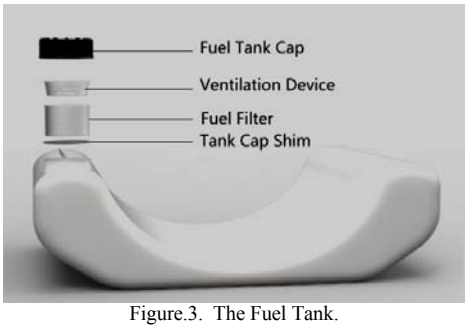

Figure.3. The Fuel Tank.

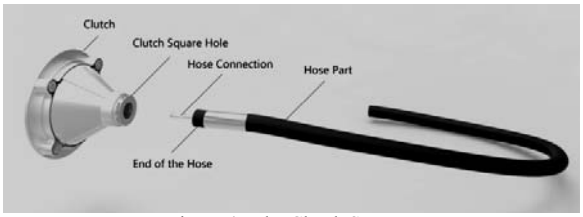

Figure.4. The Clutch System.

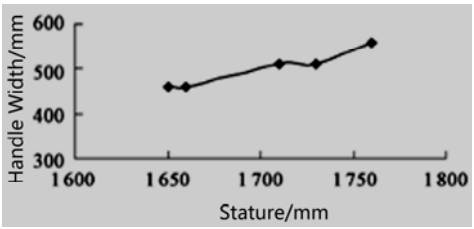

Figure.5. The Relationship Between Hand Width and Stature.

Considering the weight of the knapsack brush cutter is so heavy that need large strength to finish the operation and the environment is so hard, most of the operators are males. The data showed that the width of one's palm generally is 71~97mm. In the process of operation, the operators might be mild slippage because of palm sweaty and other objective reasons. So we should leave functional size enough. The correction range of the functional size is 13~20mm. At the same time, the appropriate functional size correction could reduce the psychological oppression. It must amend according to the specific situation of the operation.

The minimum functional size and the best functional size of products can be confirmed in formula (1). And the result is in formula (2).

$$x_{\min} = x_a + \Delta f$$
$$x_{opm} = x_a + \Delta f + \Delta p \quad (1)$$

$$x_{\min 1} = 97mm + 13mm = 110mm$$
$$x_{\min 2} = 97mm + 20mm = 117mm$$
$$x_{opm1} = 97mm + 13mm + 13mm = 123mm$$
$$x_{opm2} = 97mm + 20mm + 13mm = 130mm \quad (2)$$

It is suggested that the minimum length of the handle L should be 13cm. in order to avoid palm under too much pressure, it should not less than 10cm. If the operators wearing glove, it should add about 1.5cm error. The materials of the working rod should have vibration absorbing function. Also, they should have a certain hardness to prevent extrusion deformation and particle embedded, but not excellent to prevent the hand under high pressure in unit area during operating.

According to the known experimental results, brush cutter's front handle width W and height of the operator G have a good linear relationship. With the height of operators changing, the width of front handle is also increasing or decreasing. The variation trend is shown in Fig.5. And according to the regression analysis, we obtain the formula (3).

$$W = 0.875576G - 990.23 \quad (3)$$

According to the ergonomic anthropometry data shows, the adult males are 1678~1775mm high in our country (the data of 50%~95% males). Putting the data into formula (3), we can get the results in formula (4).

$$W_1 = 0.8775576 \times 1678 - 990.23 = 567.43$$
$$W_2 = 0.8775576 \times 1775 - 990.23 = 563.92 \quad (4)$$

Concluding that, when the handle is designed in curve shape of unequal width, the width can be controlled at 560~570mm. According to the anatomical and biological analysis of hand, the optimal grip span is 4.5~9.5cm. In order to ensure that the operator's hand has enough space for placing, there should be 6cm between the front handle and working rod.

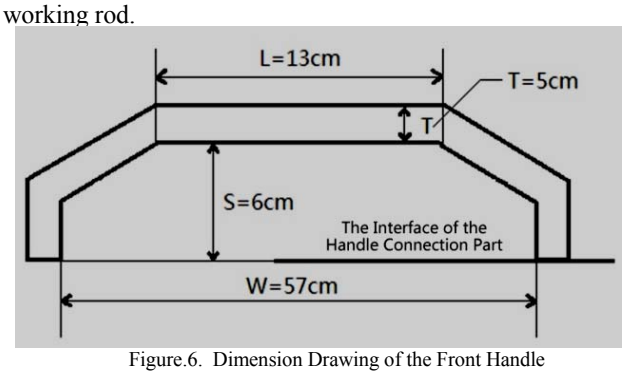

Figure.6. Dimension Drawing of the Front Handle

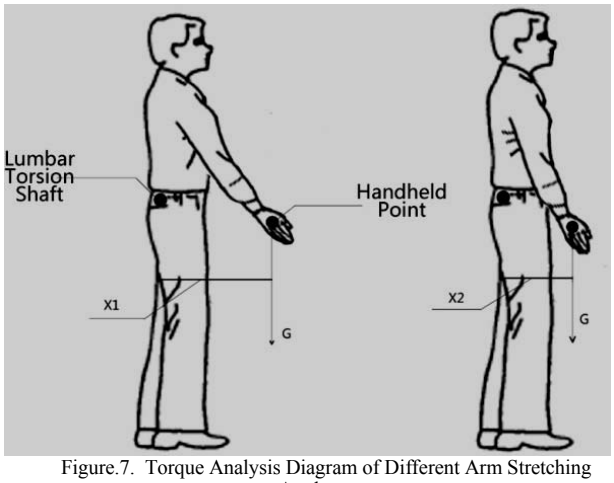

Figure.7. Torque Analysis Diagram of Different Arm Stretching Angles

According to the experience of using knapsack brush cutter and the analysis of ergonomics, we know that when people in a natural stance the stress of the back is minimum. When the operators using the same equipment in the natural stance, assuming the same handheld object's weight is G, but the arm protraction angle is different, the torque is different. As shown in Fig.7, the result is M1=X1×G>M2=X2×G.

The conclusion is that, with the increasing of the distance between handheld object's gravity point and human lumbar torsion shaft, the load torque is increasing. When using the front handle of the knapsack brush cutter, the angle between arm outstretched and natural vertical has little change. So we could ignore it. Therefore, we can regard the distance between handheld point of front handle and ground level as the hand functional height. As shown in Table 1, we could get the corresponding percentile data from the standard anthropometric data. Considering the shoes are 25~38mm high, we can get the formula (5). Calculating the distance between the handheld point and platform is 110cm, as shown in Fig.8.

TABLE I MALE ANTHROPOMETRIC DATA IN CHINA

Items	1	5	10	50	90	95
Stature/mm	1543	1583	1604	1678	1754	1775
Hand Function Height/mm	656	680	693	741	784	801

$$x_{opm} = x_a(95\%) + \Delta f = 801 + 29 = 110mm \quad (5)$$

The main purposes of the working rod are bearing the relevant parts and controlling the cutting devices. It works through the grasping of palm and fingers to move. The diameter is depended on the size of the hand. The diameter is too large or too small will affect the flexible of hand and the speed of operation, and will lead to the palm and fingers fatigue. Because the working rod of the knapsack brush cutters do not have to do precision works but help operators grasp, the size of the working rod is determined 30~40mm[11].

(1)the design of the shoulder strap's width

According to the pressure calculation formula P=F/S, the pressure P is inversely proportional to area S. when the pressure is constant, the larger is the area, the smaller is the pressure of the shoulder. So we can decrease the pressure of the brush cutter through increasing the areas between the shoulder straps and body in the range of the shoulders and necks can support.

The maximum range that shoulders could support is 1/2(width of shoulder-width of neck), without the dressing correction 13. The conclusion is that the strap width should be controlled in 5.5~6.8cm.

(2)the design of the backrest

The width of backrest of the knapsack brush cutter is depended on the chest width and hip width. The length of the backrest is depended on the length of upper part of the body. And the maximum of the width and length should not beyond the body size data, or it will bring inconvenience to operators' work.

Through the experiment and theoretical analysis, the body of the knapsack brush cutter will squeeze the human spinal bones and muscles. The traditional modelling of backrests is too simple to adapt the trend and streamline of spine. And the materials are so single that could not reduce the pressure of the spine during the operation. In the improvement design of the backrest, we should make the around parts fit the back and the middle parts keep some gaps to reduce the pressure to spine as much as possible. The material of the backrests should be vibration absorption function, strong toughness, good for the process to reduce the damage to operators in work. As shown in Fig.9 and Fig.10.

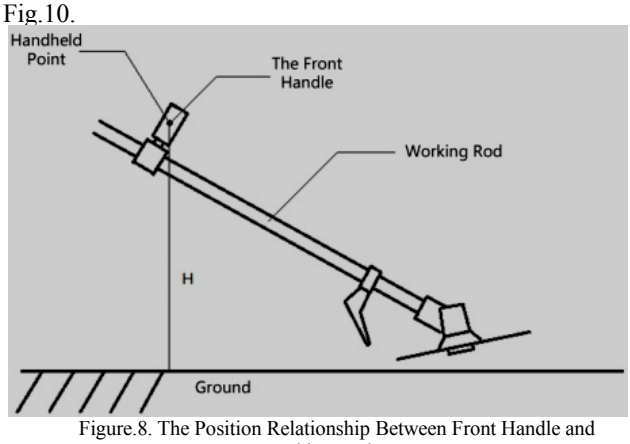

Figure.8. The Position Relationship Between Front Handle and Working Rod.

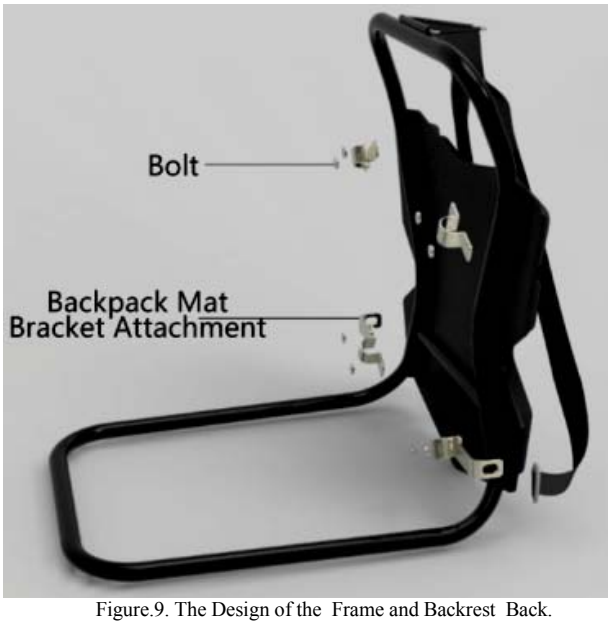

Figure.9. The Design of the Frame and Backrest Back.

Figure.10. The Whole Brush Cutter

The continuous vibration of knapsack type brush cutter will cause harm to human body, high speed cutting blade rotation may also cause damage to the human body, so the design of cutting machine safety protection device is very necessary. In this security improvements in design, it is necessary to avoid the mechanical device of threat to human health, but also to avoid the influence of environmental factors on human body.

Cutting device of brush cutter is divided into two kinds: totally naked and part exposed outside, partial nudity cutting device is provided with a row of straw bags or exhausting grass port. Considering the properties of knapsack type brush cutter work, in order to reduce the working rod and cutting device weight, reduce manpower strength load, the modified design choice of blade is completely exposed outside , give up the blade housing and a grass discharging device.

When the brush cutter begin to work, high-speed rotary blade may touch the relatively hard objects cause hard material ejection, and no guide plate guides the discharge direction clipping, clipping will be flying with the blade rotation direction, in order to protect the body from harm, in

the blade and the relative position of human feet put a blade protective cover, on which the along the plane shall not be less than the top blade, prevent the hard object Beng hurt the human body. A blade guard along the distance and the blade protective distance trajectory of planar measuring the minimum distance between the cover along with the tip can be known by the experiment and gain practical experience.

In order to reduce the human body in the process of the work of the vibration and noise of feeling, and to reduce the vibration on the negative influence of the operator the physiology and the psychology, the design of brush cutter should take feasible damping and noise reduction measures, such as adding damping link, use the vibration absorbing material and wear earplugs etc.

IV. CONCLUSION

This study analyzed the factors that brush cutter operation cause the occupational injury , and carry on the improvement design of the security on the brush cutter, abandon the design factors that does not conform to the design factors of ergonomics, and let the brush cutter achieve the standard that functions to human body posture, thence to reduce the occupational disease incidence of a disease, reduce the occurrence of occupational safety accident. Followings are the main points of design:

(1) The back cushion hollow type design, selects the new composite material capable of absorbing vibration and weight loss, the operator of the spine is not squeezed machine load, thereby reducing the back fatigue and lower back pain body injury, and improves human-computer interaction;

(2) The design of U type oil tank, puts it on the lower part of the engine, makes good use of space, and can make the machine weight more evenly distributed in the back of the operator ;

(3) The redesign of handle size, we can get a series of more ergonomic product size from the experiment and the analysis of related formula calculation, it can improve the human work fit and reduce the case rate of occupational disease that caused by the prevalence of adverse working posture at the same time.

(4) The design of blade protective cover, In the blade and the relative position of human feet placed a blade guard, make it along the plane shall not be less than the top blade, and prevent the hard object hurt the human body.

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