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Research Paper

Survey of Walking Tractor Operating Comfort in Nueva Ecija, Philippines

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聞きとり調査によるフィリピンの水田地帯での歩行用トラクタの操作性評価

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1. Introduction

This research was conducted for the benefit of agricultural machine design engineers with special interest on ergonomics or human factors engineering, so that they may develop machines which could better fit the requirements, problems and physical limitations of the intended users. The survey was conducted to be able to gather solid, up to date and reliable data regarding farm tractor operator demographics, body dimensions and problems encountered with respect to farm tractor operation. These information will allow for an in-depth look at these farm workers and for the formulation of possible intervention measures that could help alleviate their suffering.

The authors had previously undertaken ergonomic research on walking tractor handle design based on Japanese human body dimensions (Sicat, J.C.V. *et al.*, 1999) and this survey could lead to the development of such handle designs for the Filipino farmers. It relies on data collected throughout the Science City of Muñoz, in the province of Nueva Ecija, Philippines in 2001 to 2003 and describes the current farm tractor operators' population in that area.

The term farm tractor operator is used throughout this paper to denote both the full time and part time agricultural tractor operators.

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2. Method

1) The Survey Area

The survey was conducted in the Science City of Muñoz in the province of Nueva Ecija, Philippines. Nueva Ecija is the largest province in Central Luzon with a total land area of 550,718 hectares and 2002 population of 1,734,013 (Philippine Rice Research Institute—Bureau of Agricultural Statistics 2004, Philippine Rice Research Institute 1998, Libosada 2003). The province is situated in the eastern rim of the broad Central Luzon Plains, lying between 120°42′ to

121°00′E longitude and 13°49′ to 16°11′N latitude. It is bounded by Pangasinan and Nueva Vizcaya in the north, Aurora Province in the east, Tarlac in the West and by Bulacan and Pampanga in the South (Fig. 1). The land rises gradually from the swampy regions of the southwest and levels off towards the east and north. The plains break into rolling hills as one approaches the Caraballo Mountains and the Sierra Madre Mountains in the north and east. In Nueva Ecija, there exist three climate types. In the southwest, a pronounced dry season occurs from November to April while rains fall during the rest of the year. In the east, close to the Sierra Madre Mountains, rain falls evenly throughout the year while in the north and northeast, there is no pronounced seasonal variance although it is relatively dry between the months of April and November. Agriculture is the main industry of the people because of its 298,742 hectares of naturally rich soil. Crops such as rice, corn, onions, other vegetables, and sugarcane are produced in great quantities. Nueva Ecija is widely referred to as the Rice Bowl of the country producing 558,343 and 410,411 metric tons of rice in the 2002 wet and 2002 dry cropping seasons, respectively (Philippine Rice Research Institute – Bureau of Agricultural Statistics 2004 ; Provincial Trade and Industry Office 2002). The province is composed of 27 municipalities and five (5) cities, one of which is the Science City of Muñoz. This emerging city is traversed by the Maharlika National Highway going to Cagayan Valley Region and by a secondary national road going to Pangasinan. Globally positioned at 15°43′N latitude and 120°54′ longitude, the Science City of Muñoz is 147 kilometers North of Manila (City Planning and Development Office 2003 ; Science City of Muñoz 2005).

Fig. 1　Location of Science City of Muñoz

The topography of Muñoz is generally flat, equivalent to 0 to 3% slope. This is the main reason why 60.3% of its total land area is devoted to agriculture, 67.04% of which is irrigated (CPDO 2005, Department of Agriculture 2003). Consequently, this city is considered as a top ranked rice producer of Nueva Ecija with an annual rice yield of 54,383 metric tons.

2) Survey Method

Previous surveys of agricultural workers in the Philippines mainly deal in social demographics with no or very little regard for the physical and occupational problems confronting this section of society. This pioneering endeavor, together with the previous ergonomic researches conducted in Japan by the authors (Sicat, J.C.V. *et al.,* 1999, 2001) should help start a thorough and concerted effort towards work leading to the emancipation of this group from stressful working conditions.

The survey was conducted using sites' area sampling to obtain an evenly distributed representative group of 124 walking tractor operators. A sample of 2 to 3 walking tractor operators in each of the city's agricultural localities were selected based on their activity status.

The survey was conducted at the peak of the land preparation season, and as such only those operators who were actively engaged in their profession were considered for the survey. In areas where less than 3 operators are actively engaged in their profession, the respondent quota for that area was filled by picking additional respondents in areas with relatively larger active operator population. On the other hand, in areas where more than 3 active operators are present, random sampling was done.

The interviewers went to the selected operators on the field, explained the purpose of the survey, and obtained the necessary data by one-on-one interview and actual investigation. The survey questions and necessary input were guided by a survey questionnaire. This questionnaire was developed solely for the purpose of this research. All of the physical measurements needed were done on site by the interviewer teams who were properly equipped and previously trained on the proper measurement methods based on those described by the Japan National Institute of Bioscience and Human Technology (Kouchi, M. *et al.,* 1994).

3. Results and Discussion

1) Demographics

The survey indicated that the walking tractor operators' population was 100% male, 77.4% of which were married. Average age was 36.2 years with a standard deviation (SD) of 11.9.

Table 1 Body specifications of the walking tractor operators

	WALKING TRACTOR OPERATORS						
	Min	Max	Median	Mode	MF	SD	Mean
Age (year)	19	65	34	42	5.6	11.9	36.2
Height (cm)	150	180	165	165	21.0	6.2	164.9
Weight (kg)	40	85	58	58	9.7	8.8	59.2
BODY DIMENSION (cm)							
Shoulder width	36.0	49.0	43.0	44.0	16.1	2.5	43.2
Leg length	30.0	47.0	39.5	40.0	21.0	2.7	39.1
Thigh length	32.0	49.0	39.0	38.0	16.1	3.0	39.0
Ankle to sole	6.0	8.0	7.0	7.0	73.4	0.5	7.2
Foot length	21.0	28.0	24.8	24.0	25.0	1.5	24.7
Foot breadth	6.6	11.5	10.2	10.0	2.4	0.8	10.0
Arm	22.0	37.0	30.0	32.0	16.1	2.8	29.7
Forearm	21.0	36.0	26.0	26.0	23.4	2.5	26.4
Palm length	9.1	11.8	10.2	9.8	3.2	0.6	10.2
Palm breadth	7.3	9.5	8.5	8.6	4.0	0.5	8.5
LENGTH OF LEFT HAND FINGERS (cm)							
Thumb	5.2	7.3	6.2	6.2	5.6	0.4	6.2
Index finger	6.0	8.1	6.9	6.8	4.0	0.4	6.9
Middle finger	6.5	8.8	7.7	7.6	4.0	0.5	7.8
Ring finger	5.9	8.2	7.0	6.9	2.4	0.5	7.1
Small finger	4.3	6.8	5.6	5.3	3.2	0.5	5.7
LENGTH OF RIGHT HAND FINGERS (cm)							
Thumb	5.0	7.1	6.1	5.8	4.0	0.4	6.1
Index finger	5.4	8.1	6.9	6.7	4.0	0.4	6.9
Middle finger	6.2	9.1	7.7	7.1	3.2	0.5	7.7
Ring finger	5.8	8.1	7.1	7.0	3.2	0.5	7.1
Small finger	4.5	6.9	5.7	5.7	4.8	0.5	5.7

MF-Frequency of the mode
SD-Standard Deviation

The age group with the most number was the 42 year-old group with an occurrence rate (OR) of 5.6% among the operators surveyed. Height and weight averaged at 164.9 cm (SD＝6.2) and 59.2 kg (SD＝8.8), respectively. The most common operator height and operator weight were 165 cm (OR＝21.0%) and 58 kg (OR＝9.7%), respectively.

The physical measurements of the existing walking tractor operators were likewise determined to have averages of 43.2, 39.0, 39.1, 29.7 and 26.4 cm for the shoulder width, thigh, leg, arm and forearm lengths, in that order. The vertical distance of the ankle from the sole of the foot was 7.2 cm. The average foot measured 24.7 cm long and 10.0 cm wide. Palm length was 10.2 and palm breadth was 8.5 cm.

The left hand of the operators had average measurements of 6.2, 6.9, 7.8, 7.1 and 5.7 cm for the thumb, index, middle, ring, and small fingers, respectively. Meanwhile, the right hand had average measurements of 6.1 for the thumb, 6.9, 7.7, 7.1 and 5.7 cm for the index, middle, ring, and small fingers, respectively.

Average experience in tractor operation was 8.7 years (SD＝6.6) with 18.5% of the respondents having 10 years of experience.

2) Tractor Specifications

The most widely used walking tractor power unit was the 11.8 kW engine (OR＝20.2%) although the over-all average engine size was 6.8 3kW (SD＝2.72). This implied the popularity in the use of walking tractors in the Science City of Muñoz, Philippines. Average handle height was 88.0 cm (SD＝7.3) and width was 63.6 cm (SD＝2.8) as shown in Fig. 2.

The most widely used walking tractor engines were Kubota, Briggs and Stratton, and Yanmar cornering 36.3%, 24.2%, and 23.4% of the actual units surveyed. The Kubota share was dominated by Kubota ER-65 taking up 35.6% of this brand's population. Briggs and Stratton units were only classified into the 7.4 kW and 11.8 kW engines with the latter taking up the mammoth's share of 73.3%. The Yanmar's 23.4% share of the engine population was widely distributed among the 16 model types available on the field. The lesser known engine brands made up the remaining 16.1% of the walking tractor engine population.

Fig. 2　Typical Philippine made walking tractor

Among the 31 walking tractor chassis brands that were surveyed, AGSAO, FIMCO, JV Ocampo and SMC portrayed dominance by taking up 14.5%, 14.5%, 13.7% and 12.1% of the chassis population, respectively. Almost all of the chassis being used by the Science City of Muñoz operators are Philippine made/brands.

3) Working Conditions

Analysis of the survey results also showed that 100% of the operators had an alternate operator. Likewise, walking tractor operation was concentrated on both primary and secondary tillage operations with 98% of the operators surveyed having experienced doing both kinds of work. Only 2% were exclusively doing either primary or secondary tillage work. This clearly showed the versatility of the walking tractor in doing farm work, and the extent with which operators worked on the farm.

4) Problems Encountered

The problems encountered by the walking tractor operators were initially grouped into the following classifications : 1) engine related,

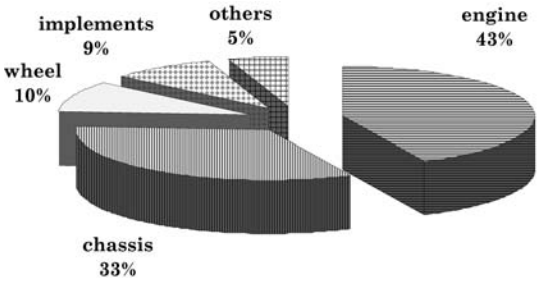

Fig. 3 Relative distribution of the problems encountered by the walking tractor operators

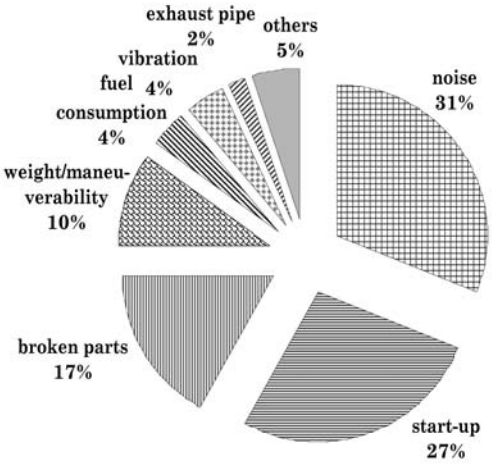

Fig. 4 Distribution of the engine related problems

2) transmission/chassis related, 3) wheel related, 4) implement related, and 5) others. Majority of the problems were engine and transmission/chassis related which comprised 43% and 33% of the operator responses, respectively. Meanwhile, Figure 3 indicated that 10% of the responses made were about wheel related problems, 9% on implement related problems and 5% on other problems.

(1) Engine Related Problems

With respect to the engine related problems, excessive noise, 31% and engine starting problems, 27% dominated the total responses in this category. Broken parts (17%), excessive engine weight leading to difficult maneuverability (10%), fuel related problems (4%), excessive vibration (4%), exhaust pipe position (2%), and others (5%), comprised the remaining engine related problem as seen in Fig. 4. The fuel related problems mainly focused on the relatively high fuel consumption of the engines and the desire for a less costly fuel. Exhaust pipe problems mainly dealt with the operators' preference for a higher exhaust pipe. The other engine related problems which did not fit into the above categories were those pertaining to non-availability of replacement parts, research on a maintenance free engine, preference for a bigger engine, and excessive belt wear. One respondent even requested for research on an engine that could run on water alone.

(2) Transmission/Chassis Related Problems

As for the transmission related problems, almost half of the responses (49%) showed excessive wear of the power transmission system. It must be noted here that almost all of the walking tractors surveyed were Philippine made and employed the chain and sprocket (or chain and gear) system. With utmost focus on simplicity and economy, local fabricators had used a design that did not have a provision for chain tension adjustment thus causing the chain to slip after a certain degree of wear on either or both the chain and gear parts. The operators found this design as very uneconomical as they had to replace the chains and gears almost every season in order to minimize the bogging down of the walking tractors in the middle of field operations.

The other engine related problems are shown in Fig. 5 are the requests for adjustable handle bars (13%), broken parts (12%), poor workmanship (10%), clutch system problems (7%) and others (9%). Some 15.3% of all the operators surveyed believed that a provision for handle bar adjustment would minimize body fatigue during on-field operations. Poor workmanship comments focused mainly on the cracking of the engine base and some other parts of the chassis body. Meanwhile, clutch system problems were dominated by the clutch lever posi-

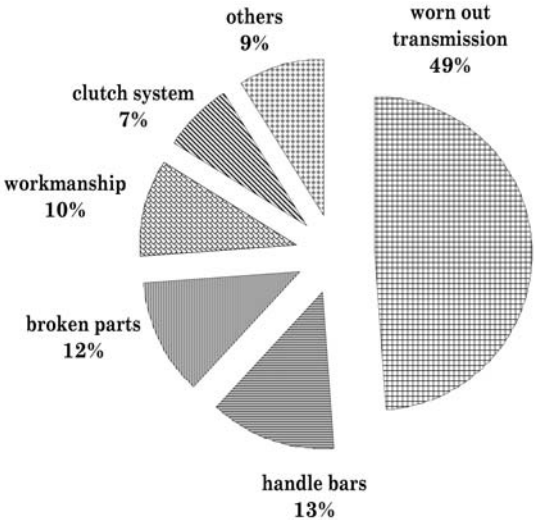

Fig. 5　Distribution of the transmission/chassis related problems

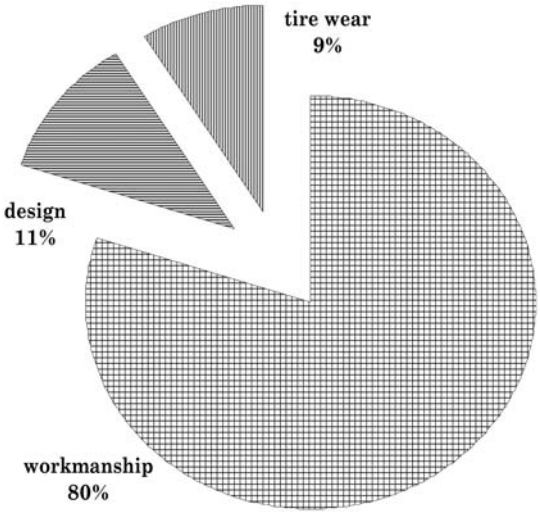

Fig. 6　Distribution of the wheel related problems

tion and stiffness. Other notable chassis related comments were preference for a propeller shaft type of power transmission, added protection from mud, provision for a backward movement of the tractor, and a bigger built-in toolbox. The last comment could be an after shoot of frequent break down experienced by the operators in the middle of field operations.

(3) Wheel Related Problems

Wheel related problems were also enumerated during the survey. A clear majority or 80% of these comments was related to poor workmanship (Fig. 6). These were mostly based on the frequent cracking of the cage wheels while some were about the rapid wear of the wheel axles. Other notable comments included requests for wider cage wheels and requests for rubberized cage wheels.

(4) Implement Related Problems

Implement related problems could be classified into two major categories : workmanship and design. Half of the responses cited poor workmanship while 47% had comments on implement design, and the remaining 3% cited a preference for the use of rotary tillers instead of the widely used disc type tillers.

Most of the comments on workmanship reported easy breakage and poor material choice leading to fast wear of specific parts. Design problems made mention of the perceived inadequate cutting width, and inadequate provision for adjustment of implement position. Some operators also mentioned the need for a design that would allow hassle free attachment and removal of implements. An operator likewise mentioned about the commercial implements' inability to cut the soil at the paddy fields' borders.

(5) Other Problems

As mentioned earlier, 5% of the problems enumerated by the walking tractor operators cannot be classified into the previous four groupings and thus enumerated in this section. Almost half (45%) were direct comments about the need for roof or any protection against sunlight (Fig. 7). It showed that the operators perceive that excessive exposure to sunlight was an added disadvantage to their profession. Furthermore, 36% of the comments in this category showed the need for an operator's seat. These operators believed that walking behind a tractor was too taxing on their health and endurance in performing a certain job. Other comments included the need

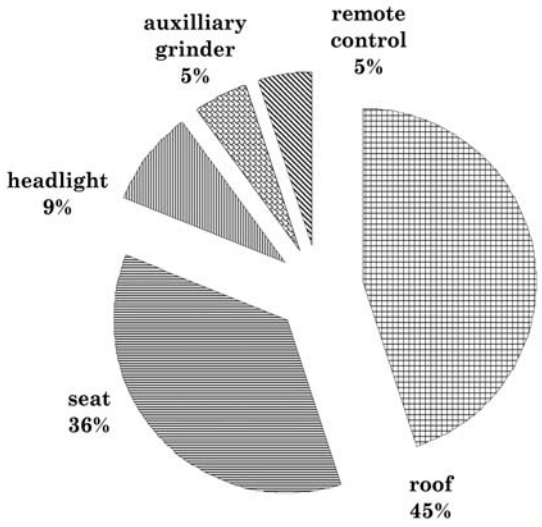

Fig. 7 Distribution of the extraordinary requests by the walking tractor operators

for a headlight, the possibility of attaching an auxiliary grinder on the flywheel, and the need for a remote controlled walking tractor operation.

(6) Across Classifications

The comparison of all of the problems mentioned by the walking tractor operators, noted that excessive transmission wear is the most prevalent at 58.1%. Excessive engine noise came second with 48.4% and engine start-up problems at third with 41.1%. The problems on cage wheel workmanship and broken engine parts were also mentioned by 29.8% and 26.6% of the respondents, respectively.

Problems regarding the need for handle bar adjustment, excessive engine weight which led to difficult maneuverability, and trailing implement workmanship had the next identical rating of 15.3%. The least mentioned problems were the need for better trailing implement design and concerns for broken chassis parts, with identical 14.5% response rate.

As a final analysis of the data, all the ergonomic related problems enumerated during the survey were extracted and tabulated for comparison. It turned out that 39% of all the ergonomic related problems pertained to excessive noise. A total of 60 operators or 48.4% of the total respondents had mentioned excessive engine noise as a farm operation problem. Ranking second in terms of operator concern was the handle bar design. More than 15% of the operators believed that the provision of an adjustable handle bar which could fit the different operators' needs and body configurations would help reduce fatigue and increase the level of operator comfort during actual field operations. The relative distribution of the other ergonomic related problems was shown in Fig. 8.

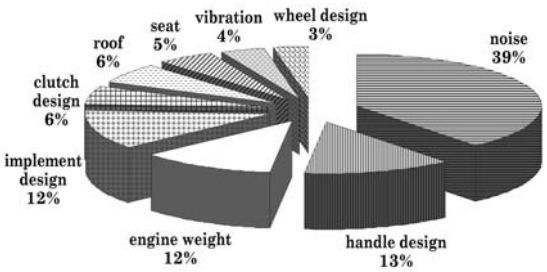

Fig. 8 Distribution of the ergonomic related problems encountered by the walking tractor operators

4. Conclusion

This study conducted in the Science City of Muñoz, in the province of Nueva Ecija, Philippines established the basic demographics and body measurements of 124 walking tractor operators. The study revealed the walking tractor chassis and engines most widely used by farmers in the area. It was noted that almost all of the chassis surveyed were Philippine made/brands. The notable problems mentioned by the walking tractor operators were excessive transmission wear (58.1%), excessive engine noise (48.4%), engine start-up problems (41.1%), handle bar design (15.3%) and implement design (14.5%). The results highlighted an urgent need for further research on the improvement of the walking tractor considering the above mentioned problems.

Key Words

Philippines, walking tractor, operator comfort, machine design, survey, physical measurements, ergonomic

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要　旨

本報はフィリピンにおける農業用機械・機具の設計要素を明らかにする事を目的として，歩行用トラクタを利用した農作業における人間工学的な諸問題を 124 名のオペレータから聞き取り調査したものである．また，歩行用トラクタの設計要素を人間工学的に検討するための基礎資料としてオペレータの身体的調査を同時に行った．調査はフィリピンの水田地帯であるヌエバ・エシハ・ムニョスにおいて 2001–2003 年に実施した．その結果，同地域で歩行用トラクタを使用しているオペレータの身体的特徴を明らかにする事が出来た．また，歩行用トラクタは，主にクボタ，ブリッグス・ストラトン，ヤンマーのエンジンが使用され（36.3%，24.2%，23.4%），エンジン出力は平均 6.83 kW（SD＝2.72），トラクタシャーシは AGSAO, FIMCO, JV Ocampo, SMC が 14.5%，14.5%，13.7%，12.1% を占め，シャーシのほとんどがフィリピンブランドであった．また，メカニック的な問題と人間工学的な課題としては，ベルト・チェーンテンションがないなどの不適切な変速機構の破損・損傷による疲労（58.1%），エンジン騒音（48.4%），エンジン始動トラブル（41.1%），ハンドルバーの設計（14.5%），作業機の設計（14.5%）に関する不満が多く，今後改善に取組む必要があることが明らかになった．

キーワード

フィリピン，歩行用トラクタ，運転者の快適性，機械設計，調査，身体測定，人間工学