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IDENTIFYING TRIGGER FEELING FACTORS

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ABSTRACT

Trigger mechanism design in power hand tools is of great importance for communicating with the operator and for providing feedback on operational functioning. Therefore, for a successful power hand tool design, knowledge about how the trigger mechanism feels is required.

This study aims to define and investigate the design factors related with trigger tactile feeling for electrical right angled nutrunners. A Kansei Engineering (Affective Engineering) study has been conducted for a comparison between users´ (operators that work at an automotive assembly plant) and product developers´ (product development group of a power hand tool manufacturer) to find common and differing semantic expression dimensions for that. 124 Kansei words (descriptors) were collected from literature, interviews and workshops. These words were reduced to 52 by affinity analysis and evaluated by operators and product developers using semantic differential technique.

From the operator group`s responses six factors (explain 87% of the variation) were identified as, "professional performance", "safety and tactile feeling", "usability", "smooth operation", "communication and durability", "convenient and comfortable" to define trigger feeling. Correspondingly, five factors (explain 89% of the variation) "robust and appealing", "ergonomics and operator performance", "controllability and predictability", "creativity and modern" and "powerful" were distinguished from the product development group. Results showed that the start phase and especially quick start of trigger mechanism is more important to operators, while end feedback is more important to product developers. Soft start of the trigger is correlated with ergonomics, optimal, clear operation and performance for product developers while soft start together with end feedback are associated with well-built, convenient and safe trigger characteristics for operators. According to the results from average ratings, the Kansei word "ergonomic" has been rated as the most important descriptor for trigger feeling together with "user-friendly", "easy to use", "long life time" and "comfortable" for both groups.

Keywords: Product development, semantic meaning, switch design, powered hand tools

1. INTRODUCTION

The human factors (ergonomics) design philosophy has shifted focus from analyzing functional aspects of product system performance, to include the users' affective experience as well as satisfaction from the human-product interaction.

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The capability of ergonomics to identify user's desires developed during the last decades of the 20th century under the name of sensibility engineering or Kansei engineering [1]. Kansei engineering is defined as translating consumers' affective responses to new products into ergonomic design specifications [2]. In the same way, Kansei Engineering can be used to translate users' affective demands to product design specifications considering ergonomic design rules[3]. It is argued that to Kansei means "to feel to the core" [4]. The word of Kansei, *if used in engineering and business*, should be considered to be a series of information processing processes of sensation, perception, cognition, sentiment and expression[i] related to a physical product or a service [4]. The term "Kansei" is referred to emotions in Japanese as, "an individual's psychological feeling and image resulting from a series of information processes from a certain artifact, environment, or situation" [5].

Trigger feeling design in power hand tools is of great importance to communicate with the operator and to provide feedback on operational functioning. Therefore for a successful power hand tool design, knowledge about how the trigger mechanism feels is required.

The switch design process depends on the following factors to provide the most direct link between operator and process [6].

- What is being controlled—the process
- How it is controlled—the type of control system
- How the control is used—human factors
- The service conditions—electrical, mechanical, and environment

The operator brings into the system many intangible parameters (common sense, intuition, judgment, and experience)—all of which relate to the ability to extrapolate from stored data, which sometimes is not even consciously available [7]. In general two constraints need to be considered that exist in designing man machine systems [7]:

- The abilities of the average operator
- The amount of information and control required by the process

This study aims to identify the important semantic factors related to trigger tactile feeling for electrical right angled nutrunners. The underlying semantic factors of trigger feeling in using right angled nutrunners, as well as their relative importance, are unknown. In literature until now, a few studies have been conducted from the point of view of ***Kansei*** engineering to evaluate switch characteristics in general but desired trigger characteristics for nutrunners have not been identified.

2. LITERATURE

The studies on triggers and switches in general have mainly been concerned with human physiology and the physical characteristics of the triggers such as *trigger force [8], trigger size effects [9], manual forces associated with triggers [10] and subjective discomfort [11]*. A recent paper proposes a new evaluation method of assessing feelings in switch-pressing motion based on the surface electromyogram (sEMG) signals [12]. The operational requirements of the push-button as a control switch comprised the following qualitative descriptors [13]: *Accessibility, Ease of use, Freedom from errors and Safety*. However we need more descriptive information for design of trigger swtiches of powered hand tools.

The relatedness of a selection of descriptors for comfort feeling in using hand tools was investigated in a recent study [14]. Six comfort factors could be distinguished as *"functionality", "posture and muscles", "irritation and pain of hand and fingers", "irritation of hand surface", "handle characteristics", "aesthetics"*. These six factors can be classified into three meaningful groups: functionality, physical interaction and appearance. Functionality and physical interaction are the most important factors related to comfort when using screwdrivers and paintbrushes, and functionality was the most important factor when using handsaws [15].

It is defined that dynamic mechanical properties of "stiffness", effective mass, and "damping" are related to a muscle's capacity to react to rapid forceful loading in hand tools, resulting in increased strain of the muscle [16]. Looking at the literature on switch design three *linear switches were* tested [17]. Typical descriptors for these switches are "clicky," "smooth," and "mushy," – words which give a sense of the highly qualitative state of the art in switches. The "clicky" switch found to have two stable states, similar to a retractable ballpoint pen. The "smooth" switch is exactly that, a smooth momentary switch, with no intentional features other than a solid feel. The "mushy" switch described as a momentary type, but with a discernable detent or "over travel" feel. In design of rocker switches three design factors from 29 Kansei words were identified to evaluate rocker switches namely "robustness", "precision" and "design" which were strongly influenced by the zero position, the contact position the form ratio, shape and the surface of the rocker switches [18].

Sensory tests have been made by a questionnaire using the words "*initially smooth", "deep clicking", "stiff" , "arriving shock", "clear", "loud" "sound", "stiff sound", "sharp sound*". The tests were carried out to acquire sensory data that relate both to the feeling and the switch's physical characteristics. The pattern of the degree of the "touch feeling" expressed by the words used for training the neural networks, and the physical characteristics of the switches were used as the output data [19]. "Operation feeling" for keyboard switches [20] was investigated by means of Kansei Engineering. The reaction force values needed to design keyboard switches and evaluation words for human feelings were obtained. The use of dual scaleing showed that some of relations between a reaction force and the quantified data of a word used to evaluate a touch feeling were nearly linear [20].

3. METHOD

Two studies were performed to answer the research questions. In the pre-study all possible descriptors of trigger feeling were collected and a first selection was made. In the main study, first the importance of the descriptors to give desired trigger feeling was studied. In the main study the selected 52 words were evaluated on 5-point scale of importance. The importance scale was labeled using the following words "not important", "somewhat important", " important", "very important" and "extremely important". From the responses a comparison was made between users (operators) and product developers to find common and differing dimensions.

The subjects were selected from operators and product developers to see if semantic dimensions differ to describe trigger feeling. The operator group consisted of 15 (4 female, 11 male) operators (experience 1.5 -10 year) working at a vehicle assembly plant in Sweden. The product development group were 11 persons (2 female, 9 male) consisting of technicians (3), ergonomists (3), design engineers (5) from a hand tool manufacturer.

3.1 Pre-study –Affinity Analysis

The aim of the pre-study was to compose a 'complete' list of descriptors that could possibly underlie trigger feeling. 124 Kansei words (descriptors) were collected from literature databases (Science Direct, Scopus, Ergonomics Abstracts, IEEE) and from interviews with technicians, product designers. A workshop has been conducted first to review the collected words and discuss the possible underlying dimensions with product developers' using Affinity Analysis. Affinity analysis is a common technique in Kansei Engineering to identify and classify Kansei words that may represent customer needs.

3.2 Main study

First average ratings for the Kansei words were found from subjects' responses. To obtain averages frequencies of ratings were used to weight each trigger feeling descriptor. Next Mann–Whitney U-test was used to analyze if there were differences between preferences of the product design group and the operators. This test is used in guarding against differences in location [21].

For the following stage 23 questionnaire items from the product development groups` responses and 29 items from the operator group`s responses were submitted to factor analysis based on principal components. For selecting related scale items, item-total correlations were computed based on summarized responses of the judges (correlations >.60 were selected as significant). This analysis reduced the feeling descriptors to a smaller number before conducting principal component analysis. Principal components analysis was performed on the responses gathered from the two groups in order to investigate correlations among subsets of responses to Kansei words (factor scores were suppressed that are below 0,5). An initial number of possible factors (based on components with eigenvalues greater than 1) were derived.

4. RESULTS

4.1. Pre study

Collected words were reduced to 52 by a workshop with an ergonomist, product design engineer and a technician using Affinity analysis. The words were grouped according to whether they represent technical characteristics, (release feedback, soft start) and feeling descriptions (comfort, creative etc.). Those technical descriptors are given in Table 1. Negative descriptors were eliminated from the collected words. According to the workshop, five main affinity clusters were identified namely "quality feeling", "trigger mechanism", "communication with operator," "trigger safety" and "general needs".

Examples of Kansei words selected to describe:

-"quality feeling" cluster are; *distinct, exact, comfort, long life time, precision, professional, repetitiveness, robust, solid, well-made, and precision*.

-"trigger mechanism" cluster are; *advanced, balanced mechanic, exact, friction, response, signal giving and compact.*

-"communication with the operator" cluster are; *good response, feedback, trust giving, repetitive, feedback while trigger release, performance, soft and quick stop*.

- "trigger safety" cluster are*; logic, right push force and stable*.

More validation is required if these dimensions can be used to define trigger feeling. Therefore the same words used for the affinity analysis is subjected to evaluation of product developers and operators in the next stage.

4.2 Identification of important Kansei words

In Table 1 based on the average ratings of subjects for the technical parameter descriptors "quick and soft start", "feedback at trigger release and end"; and "soft stop" were perceived as very important by both product developer and operator groups.

Table 1: Sorted average ratings for technical descriptors (highest to lowest)

Triger Feeling Kansei Words	Operator group	Product development group	Triger Feeling Kansei Words	Operator group	Product development group
QUICK START	3.93	3.82	**RELEASE FEEDBACK**	3.73	3.91
SOFT START	3.80	3.64	**SOFT STOP**	3.73	3.18
END FEEDBACK	3.67	4.09	**FRICTION AT PUSH DOWN**	3.07	2.36

Table 2 shows the Kansei words except technical descriptors that are important to describe trigger feeling. The first 26 words were rated as "very important" and "extremely important" based on the frequency weighted ranking* Those words appear as important for both the operator and the product development group. These words are shown as sorted for the operator group in Table 2. The Kansei word "ergonomic" has been rated as the most important descriptor for trigger feeling (in Swedish *triggerkänsla*) together with "user-friendly", "easy to use", "long life time" and "comfortable" for both subject groups.

On the contrary, the words "powerful", "modern", "creative", "tenacious", "high technology" and "perform" were rated relatively low by the product development group in comparison to the operator group. From the technical parameter descriptors, "quick and soft start", "feedback at trigger release and end"; and "soft stop" were perceived as very important by both product development and operator groups. There is no significant difference between the two groups on perceiving the importance of technical characteristics.

Table 2: Sorted average ratings for Kansei descriptors (highest to lowest)

No	Triger Feeling Kansei Words	Operator group	Product development group	No	Triger Feeling Kansei Words	Operator group	Product development group
1	ERGONOMIC	5.00	4.00	24	DURABLE	4.07	4.09
2	USER FRIENDLY	4.87	4.00	25	PRECISION	4.00	4.18
3	EASY TO USE	4.87	4.36	26	COMFORT	3.93	4.36
4	LONG LIFE TIME	4.73	4.00	27	WORKOUT ROUGHLY	3.87	3.36
5	COMFORTABLE	4.67	3.82	28	SOLID	3.87	3.36
6	PERFORM	4.67	2.64	29	GIVING TRUST	3.80	3.91
7	PRACTICAL	4.53	4.09	30	COMMUNICATIVE	3.80	3.27
8	SAFE	4.53	4.45	31	PROFESSIONAL	3.80	3.64
9	TRUSTABLE	4.47	4.73	32	ELASTIC	3.67	3.36
10	CONVENIENT	4.47	2.82	33	SILENT	3.67	2.36
11	CLEAR	4.40	4.27	34	POWERFUL	3.40	2.27
12	EFFECTIVE	4.40	3.00	35	MODERN	3.40	2.55
13	FUNCTIONAL	4.33	4.45	36	ROBUST	3.40	4.27
14	QUALITATIVE	4.33	3.91	37	DAMPING	3.33	3.00
15	WELL-BUILT	4.33	3.27	38	RESISTANCE	3.20	3.18
16	CONTROL	4.27	4.18	39	SOLID	3.13	3.64
17	LOGIC	4.27	3.91	40	CREATIVE	2.93	2.09
18	OPTIMAL	4.27	2.82	41	SMOOTH	2.87	2.45
19	LASTING	4.27	4.27	42	HIGH TECHNOLOGY	2.80	1.91
20	STABIL	4.20	3.73	43	RESPECT GIVING	2.80	2.00
21	EXACT	4.13	4.09	44	APPEALING	2.73	2.82
22	REPEATABILITY	4.13	4.64	45	AESTHETIC	2.53	2.55
23	LEGIBLE	4.13	4.09	46	TENACIOUS	2.40	2.00

[1]Average rating of trigger Kansei words (translated from Swedish) based on sample size (n) and frequency (f) of responses (f1*1)+(f2*2)+(f3*3)+(f4*4)+(f5*5)/n1;n2

4.3. Differences between product developers´ and operators` responses

The null hypothes is tested as H_0: The trigger description words are equally important to both operator and product development group.

To describe trigger feeling, Mann-Whitney U test on rank sums in Table 3 showed that;"effective", "ergonomic", "creative", "modern", "resistance", "exact", "optimal", "*quick start*", "stabile" and "safe" are significantly more important to the operator group compare to the product developers. On the other hand Kansei words such as "comfort", "control" and "*soft start*" were significantly more important to the product developers than the operators.

Table 3: Significant Kansei variables for subjest groups based on Mann-Whitney test

Trigger feeling descriptors	Rank Sum Product Development Group	Rank Sum	U	Z	p-level	Z	p-level	Product Development Group	Operator Group
COMFORT	206.00	145.00	25.00	2.98	0.00	3.09	0.00	x	
CONTROL	195.50	155.50	35.50	2.44	0.01	2.50	0.01	x	
SOFT START	192.50	158.50	38.50	2.28	0.02	2.37	0.02	x	
CREATIVE	93.00	258.00	27.00	-2.88	0.00	-2.97	0.00		x
EFFECTIVE	106.50	244.50	40.50	-2.18	0.03	-2.31	0.02		x
ERGONOMIC	111.00	240.00	45.00	-1.95	0.05	-2.83	0.00		x
EXACT	83.50	267.50	17.50	-3.37	0.00	-3.62	0.00		x
MODERN	101.50	249.50	35.50	-2.44	0.01	-2.55	0.01		x
OPTIMAL	105.00	246.00	39.00	-2.26	0.02	-2.69	0.01		x
QUICK START	74.00	277.00	8.00	-3.87	0.00	-4.02	0.00		x
RESISTANCE	93.00	258.00	27.00	-2.88	0.00	-3.01	0.00		x
SAFE	100.00	251.00	34.00	-2.52	0.01	-2.68	0.01		x
STABIL	98.00	253.00	32.00	-2.62	0.01	-2.70	0.01		x

x : Mann- Whitney tests for presented variables are significant at $p < .05$

4.4. Identified semantic factors for trigger feeling from the operator group

Six factors to describe trigger feeling for the operator group and the sub factor loadings are presented in Table 4. The first factor "professional performance" explains 24% of the variation. These factors have high loadings from the words professional, silent, modern, optimal, control, qualitative, tenacious and are related with release feedback. The second factor explains 18% variation of the descriptive words as the second most important component. This component shows that soft start and end feedback are associated with well-built, convenient and safe trigger characteristics.

The third factor represents "usability" explains 16% of the variation involving quick start and friction at push down in relation to easy to use, robust, comfort, communicative and long life time.The fourth factor "communication and durability" explains 13% of the variation and represents that the precision, legible, solid, durable, communication. The fifth factor "smooth operation" represents 9% of the variation and includes safe, smooth and logic. The last factor "convenient and comfortable" represents 7% of the variation and are associated with convenient, comfort and solid.

The first four factors "professional performance", "safety and tactile feeling", "usability", smooth" and "communication and durability" explain together 71% of the variation which can be accepted as a threshold value to describe trigger feeling. The selected five factors totally explain 87% of the variation.

Table 4: Identified trigger feeling factors for the operator group

	Factor 1 Professional - performance (24%)	**Factor 2 Safety and tactile feeling** (18%)	**Factor 3 Usabilit y** (16%)	**Factor 4 Communication and durability** (13%)	**Factor 5 Smoothness** (9%)	**Factor 6 Convenient and comfortable** (7%)
PROFESSIONAL	.893					
RELEASE FEEDBACK	.810					
MODERN	.756					
TENACIOUS	.742					
QUALITATIVE	.741					
ROBUST	.720		.610			
SILENT	.685					
PERFORM	.679		.574			
OPTIMAL	.661					
CONTROL	.520		.511			
END FEEDBACK		.893				
WORK OUT THOROUGHLY		.879				
DAMPING		.783				
SOFT START		.715				
WELL-BUILT		.622				
SAFE		.522			.521	
LONG LIFE TIME			.836			
EASY TO USE			.793			
QUICK START			.758			
FRICTION AT PUSH DOWN			.656			
PRECISION				.865		
COMMUNICATIVE			.533	.716		
LEGIBLE	.531			.686		
DURABLE	.557			.619		
SMOOTH					.833	
LOGIC					.648	
CONVENIENT		.650				.661

COMFORT	.509		.637
SOLID		.574	.576

4.5 Identified semantic factors for trigger feeling from the product development group

Correspondingly, five factors to describe trigger feeling for the product development group and the sub factor loadings are presented in Table 5. The first factor seems to represent variables related with “robust and appealing” and explains 33% of the variation to describe trigger feeling. This factor has high loadings from subjective (appealing, aesthetics) and an objective (e.g. user friendly, functional) dimension of “usability” in trigger design.The second factor is related with “ergonomics and operator performance” and explains 26% variation. This component shows that soft start of the trigger is correlated with ergonomics, optimal, clear operation and performance. The third factor represents “controllability and predictability of the operation explains 15% of the variation. Control, trust, safe and repeatable use of trigger button represents a dimension for a better operation feeling. The fourth factor “creativity and modern” explaining 10% of the variation represents that the product developers give importance to innovation and creativity in trigger design. The last factor “powerful” represents 5% of the variation from the ratings showing that designing powerful with high technology is considered important by the product developers. First, the three factors “robust and appealing” “ergonomics and operator performance” “controllability and predictability” explain together 74% of the variation which can be accepted as a threshold value. The selected five factors totally explain 89% of the variation.

Table 5: Identified trigger feeling factors for the product development group

	Robust and appealing (33%)	**Ergonomics and operator performance** (26%)	**Controllability and predictability** (15%)	**Creative and modern** (10%)	**Powerful** (5%)
SOLID	.934				
PROFESSIONAL	.909				
USER FRIENDLY	.893				
WELL DONE	.848				
FUNCTIONAL	.834				
APPEALING	.832				
WORK OUT THOROUGHLY	.815			.501	
AESTHETIC	.797				
SOFT START		.950			
LONG LIFE TIME		.877			
CLEAR		.872			
ERGONOMIC		.789			
EFFECTIVE		.768		.519	
OPTIMAL		.760			
PERFORM		.694			
CONTROL			.847		
TRUSTABLE			.847		
SAFE			.761		
REPEATABILITY			.706		
CREATIVE				.757	
MODERN	.577			.612	
POWERFUL	.519				.688
HIGH TECHNOLOGY					-.548

5. DISCUSSION AND CONCLUSIONS

This study explored if product developers and users have parallel opinions on customer needs to describe trigger feeling by a questionnaire for right angled electrical nutrunners. A switch system is frequently graded by the quality of the feeling when it is touched, and also by its sound while operating [18]. However while using hand tools due to high noise in the working environments sound feedback cannot be used as a feedback indicator. Instead the product developers need to understand how the operators feel when they use the trigger of hand tools. For those reasons identification of semantic dimensions to describe trigger feeling is needed for a safe hand tool design.

Based on the purpose above for the operator group trigger feeling for angled nutrunners is explained by six main factors; "professional performance", "safety and tactile feeling", "usability", "communication and durability" smoothness" and "convenient and comfortable".

For product development group trigger feeling is explained by five factors which are "robust and appealing" "ergonomics and operator performance" "controllability and predictability", "creative and modern", "powerful".

The "functionality" factor in hand tools are strongest related to comfort and "aesthetics" are found to be least related to comfort in using hand tools [14]. In comparison to that, in our study comfort was in the same factor cluster as "usability", "convenience" and "solid" for the operator group.

The results of this study are in agreement to the quality characteristics defined by affinity analysis in the preliminary study. The quality characteristics can be seen at the first dimension of factor loadings "professional performance", "robust and appealing" for the operator and product development groups.

Technical parameter descriptors selected for the study were important both for product developers and operators to describe trigger feeling while for Kansei descriptors such as "effective", "ergonomic", "creative", "modern", "resistance", "exact", "optimal", "quick start", "stabile" and "safe" were found significantly more important to the operator group and less important to product development group.

The identified factors to describe trigger feeling indicate that operator and product developers have common and differing characteristics. Considering the factors identified from the operators` responses; it was seen that the operators could easily relate the technical parameters the `intangible parameters´ that may affect their performance and job satisfaction. From the factors identified from the product developers a more general view about product design was distinguished.

In this study explorative factor analysis has used as a starting study. by using confirmatory factor analysis in the next stage we can develop a questionnaire using the factors and variables identified; and can make assessments about trigger function and to know how operators feel about new types of trigger mechanisms. The identified factors and variables are going to be used for improving physical trigger design parameters and for comparing triggers of hand tools in the future.

This study has shown that in product design and development it is essential to listen to the customer`s voice and to integrate together with the product developers` technical and scientific experience. Kansei Engineering was found as a suitable approach identifying the subjective needs of operators to better design and to develop triggers for hand tools.

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REFERENCES

[1] Lee, K.S Ergonomics in total quality management: How can we sell ergonomics to management? *Ergonomics*, Vol.48, No.5, 2005.

[2] Nagamachi, M. Kansei engineering: a new consumer-oriented technology for product development., *Occupational Ergonomics Handbook*. (eds. Karwowski. W. and Marras. W.S.. Eds.), CRC Press, New York, pp. 1835–1848, 1988.

[3] Nagamachi, M. Kansei engineering in consumer product design, *Ergonomics in Design*, Vol.10. No.2,, 2002.

[4] Nagasawa, S. Present state of Kansei engineering in Japan. *Systems Man and Cybernetics. IEEE International Conference*, Vol. 1, pp. 333–338, 2004.

[5] Nagamachi, M. Kansei engineering: an ergonomic technology for product development. *Int. J. Ind. Ergonomics*, Vol.15, No. 1, 1995.

[6] Lipták, B. G. *Instrument Engineers' Handbook: Process control and optimization*, CRC Press, 2006.

[7] Hunt, B. *Handbook of Control Room Design and Ergonomics: A Perspective for the Future*, Second Edition Editor(s): Toni Ivergård, CRC Press, 2008.

[8] Yung-Hui L.; Son-Lin C. Triggering force and measurement of maximal finger flexion force, *International Journal of Industrial Ergonomics* Vol.15, No. 3, 1995.

[9] Oh, S. and Radwin, R.G. Pistol grip power tool handle and trigger size effects on grip exertions and operator preference, *Human Factors*, Vol.35, No.3, pp.551–569, 1993.

[10] Lowe B., Kong Y., Krieg E., Wurzelbacher S., Lee S. A Field Investigation of Manual Forces Associated With Trigger and Push to Start Electric Screwdrivers, *Human Factors and Ergonomics in Manufacturing*, Vol. 17, No. 4, pp.367–382, 2007.

[11] Gerard, M.J., Armstrong, T.J, Franzblau, A, Martin, B.J, Rempel, D.M., The effects of keyswitch stiffness on typing force, finger electromyography, and subjective discomfort, *American Industrial Hygiene Association. Journal*, Vol.60, No. 6, pp.762–769, 1999.

[12] Sekiyama, K., Ito, M.,Fukuda, T., Suzuki, T., Yamashita. K., Quantitative evaluation of feeling in switch-pressing motion based on human biometric information, RO-MAN The 17th IEEE *International Symposium on Robot and Human Interactive Communication*, 2008.

[13] Moore, T.G. Industrial push-buttons, *Applied Ergonomics*, Vol. 6, No. 1,pp.33–38, 1975.

[14] Kuijt-Evers, L. Groenesteijn, Looze, M.P. de, and Vink, P. Identifying factors of comfort in using hand tools, *Applied Ergonomics*, Vol. 35, 453–458, 2004.

[15] Kuijt-Evers, L, Vink, P.., Looze, M.P. de, Comfort predictors for different kinds of hand tools: Differences and similarities, *International Journal of Industrial Ergonomics*, Vol. 37, No.1, pp. 73-84, 2007.

[16] Sesto, Mary E., Radwin, Robert G., Block, Walter F. and Best, Thomas M., Upper Limb Dynamic Responses to Impulsive Forces for Selected Assembly Workers', *Journal of Occupational and Environmental Hygiene*, Vol. 3, No:2,pp.72 -79, 2005.

[17] Weir. D., Buttolo. P., Peshkin. M.,J. E.Colgate. J.Rankin. M. Johnston Switch Characterization and the Haptic Profile, *12th Haptic Symposium on Haptic Interfaces for Virtual Environment and Tele operator Systems.* March 27-28. 2004

[18] Schütte S., Eklund J.Design of rocker switches for work-vehicles - An application of Kansei Engineering, *Applied Ergonomics*, Vol. 36, No.5, pp. 557–567, 2005.

[19] Kosaka, H., Serizawa, K. , Watanabe. K.A Universal Keyboard Switch for a Feeling Test. *IEEE Workshop on Robot and Human Communication '93.* Science University of Tokyo. Tokyo.,Japan.3-5 November,pp.225/230, 1993.

[20] Kosaka. H. Nishitani. H. Watanabe. K. Estimation of reaction force of a keyboard switch based on Kansei information using neural networks, *Networking. Sensing and Control. Proceedings*. IEEE, 2005.

[21] Siegel, *S*. Nonparametric statistics for the behavioral sciences. McGraw-Hill: New. York, 1956.

[22] Field, A. P. Discovering statistics using SPSS: and sex and drugs and rock 'n' roll (2nd edition). London: Sage, 2005.