

A Study for the Development of the Aerobic Exercise Equipment through Cooperation between Design and Engineering Fields

Focusing on the Development of Elliptical Cross Trainer

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Abstract: It is expected that the typical lifestyle of the future will be transformed into an opulent and comfortable existence as the quality of life improves due to the increase in household income and reduction in working hours. In the meantime, as the standard of living becomes increasingly more comfortable and plentiful, the toll on physical health becomes magnified as a result of obesity and insufficient exercise caused by super nutrition and change in labor conditions. This has instigated a deep awareness in fitness on the part of many people, forcing them to recognize the significance of daily exercise and physical activity. The Elliptical Cross Trainer(ECT), which has drawn wide attention recently, is a non-impact athletic apparatus that not only promotes exercise of the upper body parts in such sports as skiing but also the exercise of lower parts of the body on a treadmill. It is a type of cross training athletic gear that has been developed for aerobic exercise throughout the entire body. It has already formed a market as big as that of the treadmill in Europe, America, etc. Recently, its demand is growing sharply in the Korean markets as well as those in Northeast Asian countries. Despite such demand increase and expansion, since most of the expensive ECTs are exclusively supplied by suppliers in only a few advanced countries, localization of the ECT is urgently required in order to enhance competitiveness of Korean manufacturers and to expand the market. The ECT development project has been in full swing for approximately two year since 2004 in order to secure independent design, as well as engineering and manufacturing processes in efforts to develop a commercially viable ECT.

Keywords: *Aerobic Exercise Equipment, Elliptical Cross Trainer, User Centered Design, Cooperation, Determining Factor for the Development*

1. Introduction

This paper introduces the process and results of a design-engineering cooperative study that was performed for the development of the Elliptical Cross Trainer.

Its major contents include: ① preparation of design-engineering cooperative work details to establish the execution program, ② mechanism analysis and technology analysis to derive the machine's own operation mechanism and basic design parameters, ③ setup of purpose by status analysis (design concept): product trend analysis, user survey analysis and user environment analysis and ④ design development and proposal.

2. Aerobic Exercise Equipment and the Elliptical Cross Trainer

The demand for indoor aerobic exercise equipment is increasing rapidly because of its unrestricted advantages of time and space and the fact that training can be enjoyed regardless of outdoor weather. Widely known representative aerobic exercise equipment includes the treadmill, the bicycle ergometer and the stepper. Among these, the treadmill is the most widely distributed. However, it comes with certain disadvantages related to noise level and vibration.

Currently, the Elliptical Cross Trainer (ECT), an advanced type of exercise equipment, is drawing attention because it can solve the problems of noise and vibration caused by feet pounding on the treadmill while providing the same exercise benefit as that of the treadmill.

The ECT provides the effect of running but without any impact imposed on the leg, knee, hip, lower back, etc. Particularly, since the ECT is made to conform to the natural walking movement of the human body, it is able to maximize the exercise effect without immoderate impact being forced on the joints and muscles. By applying the regenerative braking method or the magnetic method, the exercise load can be controlled precisely in multi stages. Therefore, it provides exceptional exercise results. In addition, unlike the treadmill, it allows various types of exercises for body figure management including forward and backward walking.

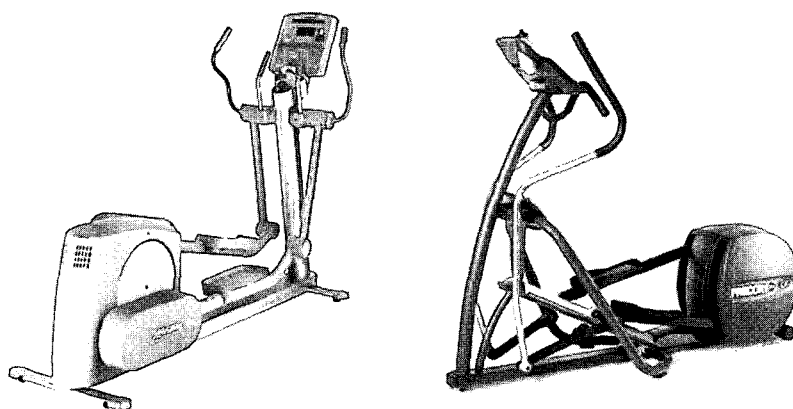


Fig.1 95XI of Life Fitness Co. and EFX533 of Procor Co.

3. Determining Factor for the Development of Elliptical Cross Trainer and Specialized Fields

In order for the ECT to exhibit itself as an innovative competitor in the field of exercise systems, it must demonstrate interaction with the contending exercise systems and their users as well as any other users that may cross the boundaries between existing systems. Therefore, the boundary conditions that determine the development of the ECT are defined by the surrounding exercise systems, surrounding environment system and the users. These boundary conditions determine the development of the ECT. According to the Theory of Product Determining Factors (Produktbestimmende Faktoren) of Arnold Schuerer, these conditions can be classified into 3 abstract factors: ① technology related factor, ② economy related factor, and ③ human related factor.

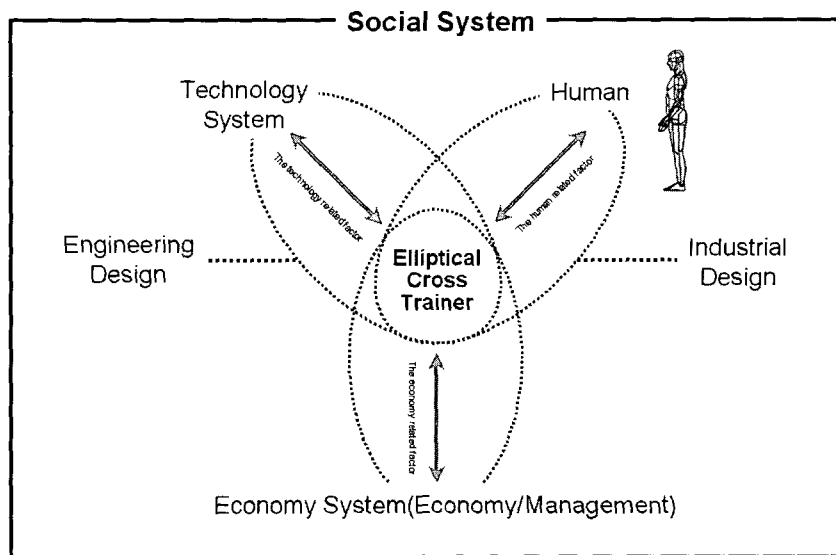


Fig.2 ECT Development Determining Factors and Specialized Fields

The technology related factor for the ECT is the factor in the technical aspect that determines the exercise equipment in the technical system. The economy related factor is the factor related to the economic efficiency in the manufacture and maintenance of the ECT in the technical system. The human related factor is the factor related to the use of the ECT by the user in the technical system. Therefore, in order to develop the ECT that satisfies the overall functions of the system to the maximum, it is essential that the experts in charge of each factor in the three fields of engineering design, industrial design, and economy and management cooperate closely.¹

Here, economy and management assume responsibility for planning and management for the realization of economical production while the engineering design and industrial design are the production technology directly related to the ECT development. Engineering design specializes in ECT technology development and

¹ Schuerer Arnold, Der Einfluss Produktbestimmender Faktoren auf die Gestaltung, Selbstverlag, Hannover, 1968.

system configuration, and industrial design specializes in the development of human-ECT interface to utilize the ECT.

The human-ECT interface, which is the object of industrial design, has actual, aesthetical and symbolic functions. The actual function is the physical and physiological actions that appear when the ECT is used by a human and physical form intervenes between them. If the physical form is recognized through the sensory organs of the human being, it activates the aesthetical function, and then it is analyzed according to the social conditions to activate a symbolic function. Therefore, the core object of the industrial design is the physical form of the ECT. However, this physical form is shaped by the result of engineering design and it is the frame that performs the required function of the technical system as well. Therefore, the form is the interface between industrial design and engineering design and the harmonization that does not give too much significance to either side is essential to achieve the objective of the development task successfully. No such harmonization issue had surfaced in the past because the production technology consisted of one integrated form. However, the production technology had become dependent on the harmonization and integration between fields since segmentation of the production technology was solidified along with its specialization.

4. Design Setup Strategy and its Execution Process

The basic process for the design setup strategy includes the establishment of a strategic objective through current status analysis, setup of strategic range and establishment of the system and execution program to execute the strategy. The contents of the design execution and strategy system are as follows.

For evaluation of the current status analysis for the objective setup and recognition of related problems, the user's needs for the ECT design were considered and a pluralistic actual condition investigation by types and attributes was performed. In the strategy range, the following items were analyzed: hardware (equipment), software (technology and function) such as characterization and localization, the userware to understand the user characteristics and to reflect the user's preference and value and, the marketware to secure competitiveness. In addition, an attempt was made to develop a specialized and differentiated design by conjunctive consideration of design plan (system integration work breakdown, etc.) focusing on the design-engineering cooperative program setup and implementation that can materialize the strategy, administration and management.

The paper made introduction focusing on major basic processes among the entire design execution processes for the ECT.

5. System Integration Work Breakdown for ECT Development

Fig.3 presents the breakdown for the design-engineering cooperative works to materialize the development of the ECT.

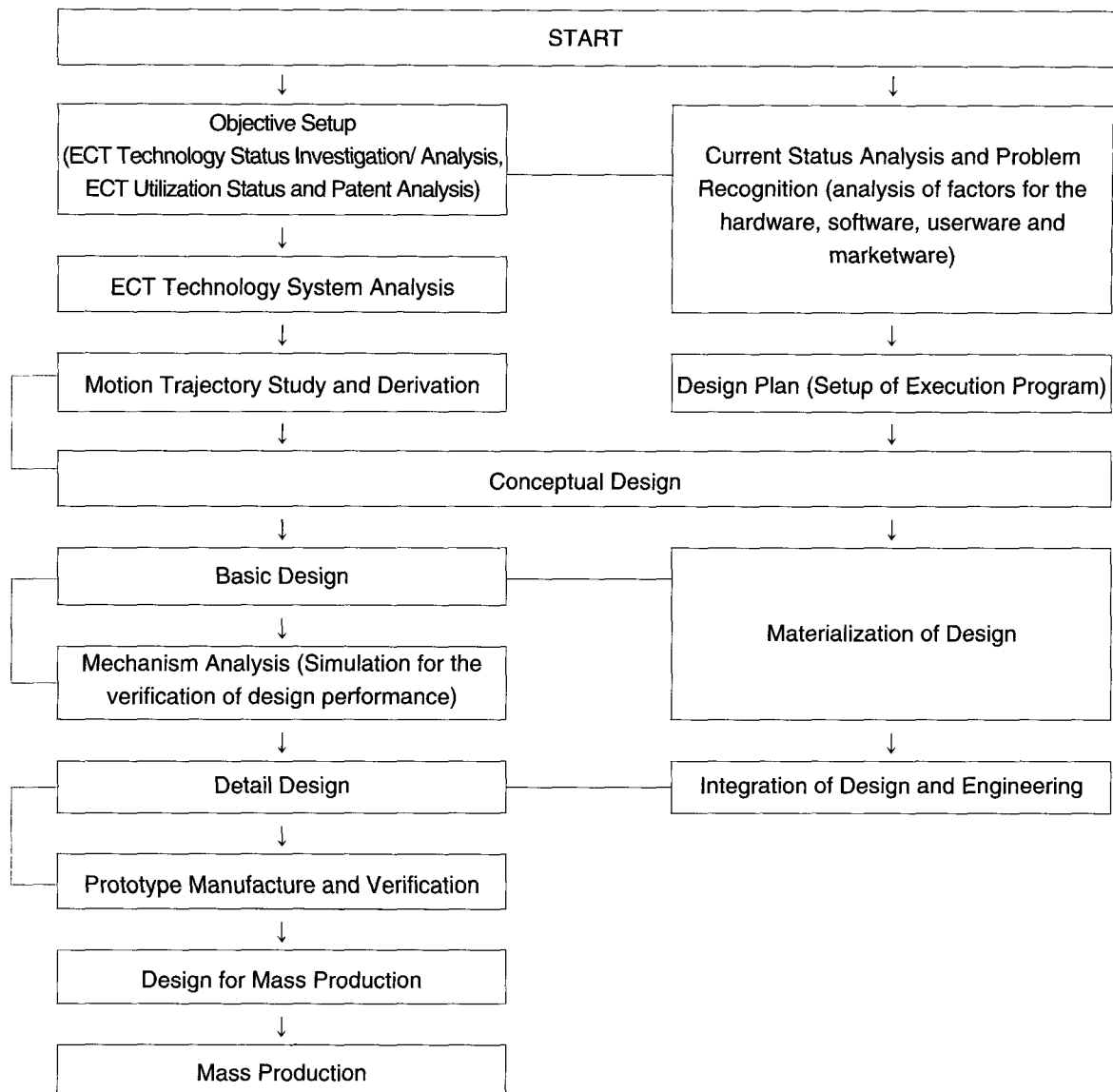


Fig.3 System Integration Work Breakdown for ECT Development

6. Basic Mechanism of Elliptical Cross Trainer

Fig.4 demonstrates the basic four-bar linkage mechanism of the ECT. The stepping plate is placed on link “A” and the motion trajectory of the stepping plate is determined according to the movement of this link. Fig.5 demonstrates the trajectory according to the link position. Point “D” is where links “A” and “C” are fixed to prevent circular rotation. Point “E” is where link “A” and link “B” are connected to make arc motion. Through such mechanism analysis, it can be estimated that the motion trajectory of the stepping plate is determined by the position and trajectory of both ends of link “A”. The items that may be considered when designing the trajectory include how to design the trajectory of both ends of link “A” and the position and angle of the stepping plate. The position of the stepping plate can be the basic design parameter for the

trajectory. In addition, by considering the body conditions of various users such as heights and stride, the mechanism that can adjust the stride should be developed to provide the optimum exercise condition.

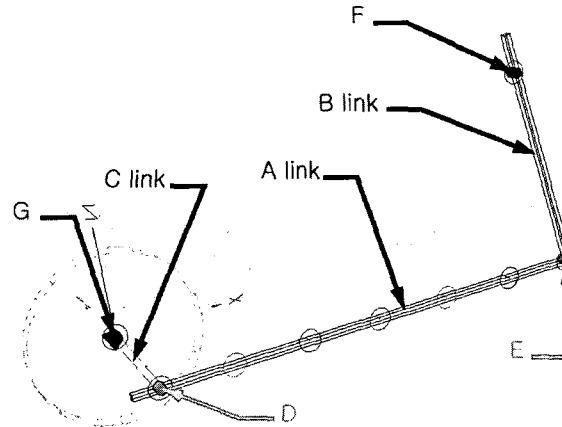


Fig.4 Structure of Basic Four-Bar Linkage Mechanism of ECT

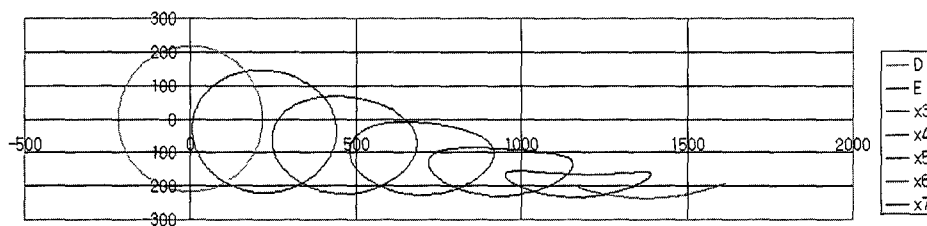


Fig.5 Process through which the motion is changed from circular motion to arc motion from point D to point E

7. Basic Design Process of Elliptical Cross Trainer

In order to setup the objective based on current status analysis, an analysis of the major technical and design trends was performed along with a user survey and user environmental analysis. Through the survey of the technology and design trend of some advanced companies as well as the existing product group of the concerned product developing company, the image concept that can reflect the product trend while preserving the product identity of the developing company was set. Moreover, through the analysis of the ECT users and the user environment, an attempt was made to establish a new ECT design concept that is more user friendly.

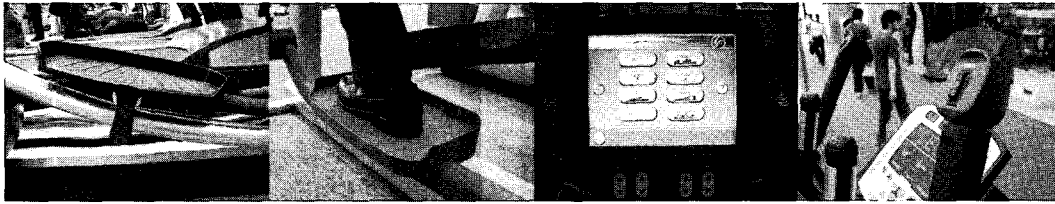
7.1 Market Status Analysis

7.1.1 Technology Trend and Major Issues

The following is the summary of the major technical trends and issues for the aerobic exercise equipment and ECT, which were analyzed focusing on the products exhibited in the 2004 International Marine Sports Products Exhibition.

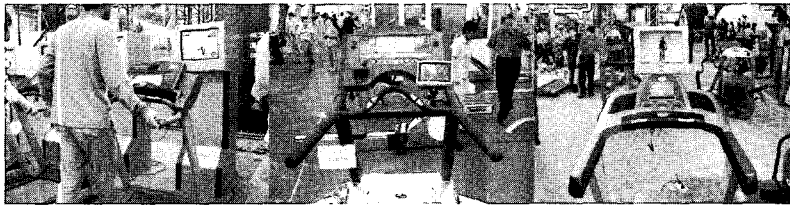
● User Oriented Design

- Design allowing the adjustment of the stepping plate considering the angle of the ankle
- Opened stepping plate design allowing easy access to the equipment
- Design of the information architecture of the LCD touch screen display with increased user convenience
- Various control devices: Control available at the handle



● Reinforcement of Entertainment Factor

-Interlocked with electronic game with animation and sound available (stimulating visual and auditory senses)



● Increased and Advance Display Combined with Digital Technology

-Application of LCD touch screen

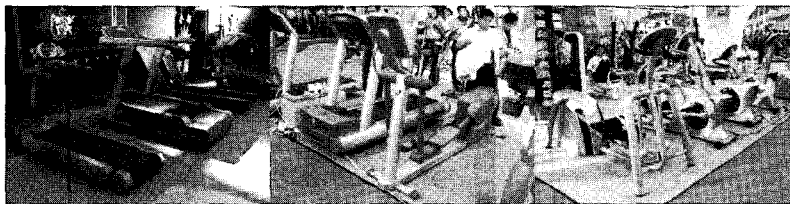
-Reinforcement of multi media function

-Various display methods (LCD, Backlight, etc.)



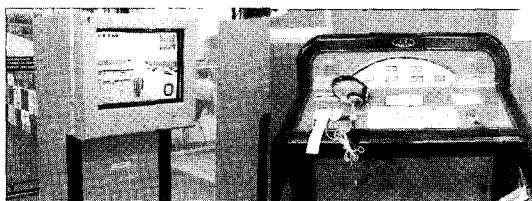
● Reinforcement of Corporate Identity through Design

-Application of company's own shape design and color



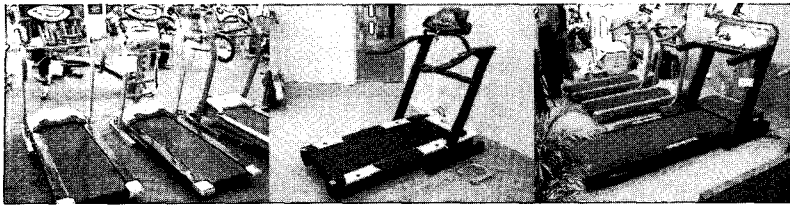
● Exercise Amount Recording and Management System

-Exercise data record and output



● Diversified Materials: Utilization of Natural Materials

-Utilization of wood



The trend of overall aerobic exercise equipment can be summarized as follows: advancement through IT technology, change from exercise oriented equipment to play oriented equipment, upgraded quality through design, and user oriented design.

7.1.2 Design Trend

Analysis was performed on the design trend of the products of advanced companies in terms of shape, color and material, etc. In addition, through the same analysis of the product group of the concerned developing company, the product identity of the developing company was examined. An image concept able to reflect the product trend while preserving the product identity of the developing company was established using the results of the analysis and examination. The analysis of the design trend was performed through image scale analysis.

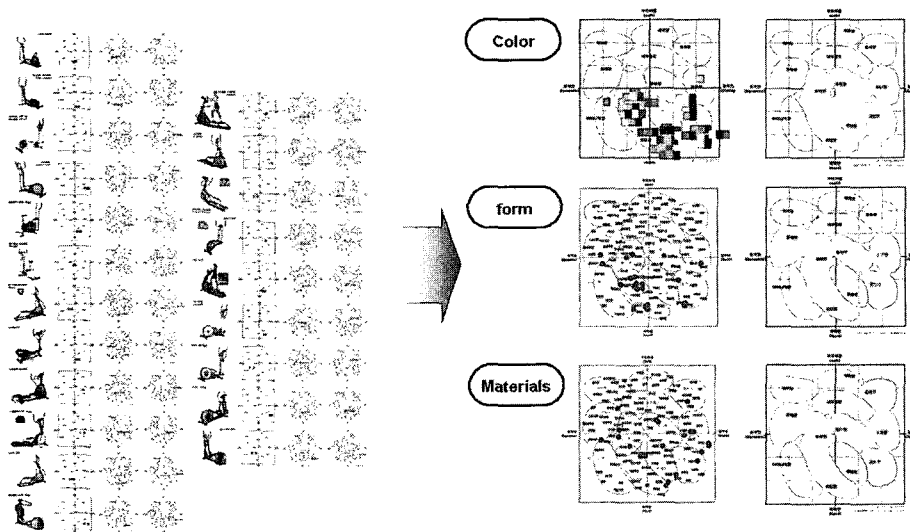


Fig.6 Design Trend Analysis of ECT of Advanced Companies

The result of the design trend analysis indicated that the products manufactured by advanced companies were distinct in regards to the shape and color of the frame and cover of the exercise equipment according to the characteristics of the product group while the majority of products manufactured by the “M” company (the concerned product development company) presented a heavy and hard functional image

7.2 User Survey

The user analysis should begin with the question, “Who is the customer?” The analysis will be made

based on the information regarding the major users, the target market, the purchase quantity and purpose of use. Particularly, modification in the customer's desire and the need for product or service improvement according to such desire must be checked through continuous observation of customers in the same manner as may be done for other analysis items.

7.2.1 Analysis on User Group

For the detailed and accurate analysis of users, surveys and direct interviews were carried out for 100 fitness club users. In addition, the user group was subdivided based on the areas of social interest including consumption, culture, value and consciousness according to the characteristics of the users.

From this it can be known that fitness clubs had a variety of user groups, which were evenly distributed throughout the various generations. The user group was sub-classified into conscious group, core group, behavior group and follower group as shown in Table 1.

Table 1 Analysis of Fitness Club User Groups

Classification	Description	Characteristics	Ratio (%)
Conscious Group	Political consciousness group -Age from 24 to 45/professionals and white color class	-Prudent/Rational -Internet audience -Early majority -Corporate watchdog	11
Core Group	Social consciousness leading group -Age: 20's/college students and social life beginners	-Innovative/Sensitive -Active in Internet -Innovative -Corporate watchdog	13
Behavior Group	Consumption and culture interest group -Age from 17 to 24/high school students and college students	-Positive/Sensitive -Internet entertainer -Early consumer -Product consumer	27
Follower Group	Group that values individual worth -Age: 30's/house wives, salaried men	-Negative/Passive -TV audience -Later majority -Corporate supporter	49

7.2.2 User Needs Analysis

In most cases, the expectation of the users having similar purpose regardless of generation pertained to the result of the exercise. However, one of the characteristics discovered through the survey is that they were more interested in 'the function' than 'the technology'. They clearly expressed what they wanted to get from the effect that the technology had, that is function. Unlike what they had wanted from the products in the past, they desired various and differentiated products. This is also one of the representative characteristics. They wanted to be able to adjust even the most commonly used exercise equipment in fitness clubs to fit their body condition or to be able to frequently change the system setups. Such requirements and characteristics that were different from those in the past should be reflected as ideas at the product development stage.

The consumer's needs presented by the user survey are as follows:


- Attractive element: The products having no element to attract and maintain the user's interest are thoroughly turned away by the user.
- Expectation about the product and service fit to individual taste
(Consumer → Prosumer) Highly differentiated products and service
- Desire not only to have the opportunity to correct their own mistakes but also to frequently change the selections they made
- Desire to experience visual stimulation during training
- Interest in what the technology does for them without being impressed by the technology

7.3 User Environment Analysis

The elements that satisfy the user's desire are not limited to the product. Particularly, the impact on the environment under which the product is used has dominant influence on the usability. The direction of the product development can be specified through not only the usability of the product but also the analysis of tangible and intangible space in which the product is used.

The usage environment of the ECT is classified into those of household and fitness club. In this development project the usage environment was analyzed by limiting it to the usage environment of the fitness club equipment at which the developed product aims.

Table 2 Requirements for Products for Fitness Clubs

Usage Environment	Requirements
 <ul style="list-style-type: none"> -Price -A/S -Brand -Reliability -Robust -Simple maintenance -Harmony with club image -Arrangement considering groups 	<ul style="list-style-type: none"> - Introduction of All-In-One system : Taking care of the products starting from the point of delivery and including after sales service - Various options : Color selection, surface finish, etc. that correspond with club image - Preference for the product requiring no after sale service : Preference for the product having low failure rate to the one that guarantees good A/S service. - Compatibility of parts - Customized system : The product can be reconfigured according to the customer's requirements. (Size change should be available) - Service manual

8. Design Concept for Materialization of Design

By the change of the consumer's consciousness, the consumer's value standard is modified according to their sensitivity and individuality rather than physical factors such as price or function. Such change has

resulted from the fact that the existing exercise equipment has become equalized and uniform technically and the selection range of the consumers has become wider with the advent of IT technology grafted models. The qualitative change consciousness, tendency of individualism and pursuit for the rationality of the consumer result in the necessity for the pursuit of the ECT according to the new user centered concept.

The user of the exercise equipment considers physical factors first. This is the primary characteristic of the exercise equipment. In order to satisfy various users' sensitivity about such physical and functional product, firstly, the development of style (modeling) aiming at a specific consumer group should be refrained from. Secondly, as the exercise equipment has a clear purpose of use, it must function perfectly. For this arrangement, a convenient facility that can maximize the exercise effect of the user without interfering with the exercise must be provided. Thirdly, the sensitive factors that can help the users who feel weary and experience difficulty during their work out must be considered. Here, care must be taken to apply the sensitive factors offering consideration to all users by taking into account the fact that the exercise equipment is used by a wide range of user groups. Fourthly, considering the future usage environment, information technology must be introduced aggressively. Finally, the differentiated design factors that can provide users with new experiences including color, quality and story about the product must be studied and applied.

9. Design Proposal

The proposed ECT design applied the design concept discussed in Section 8. In addition, it focused on the stable posture for exercise and the visualization of exercise effect.

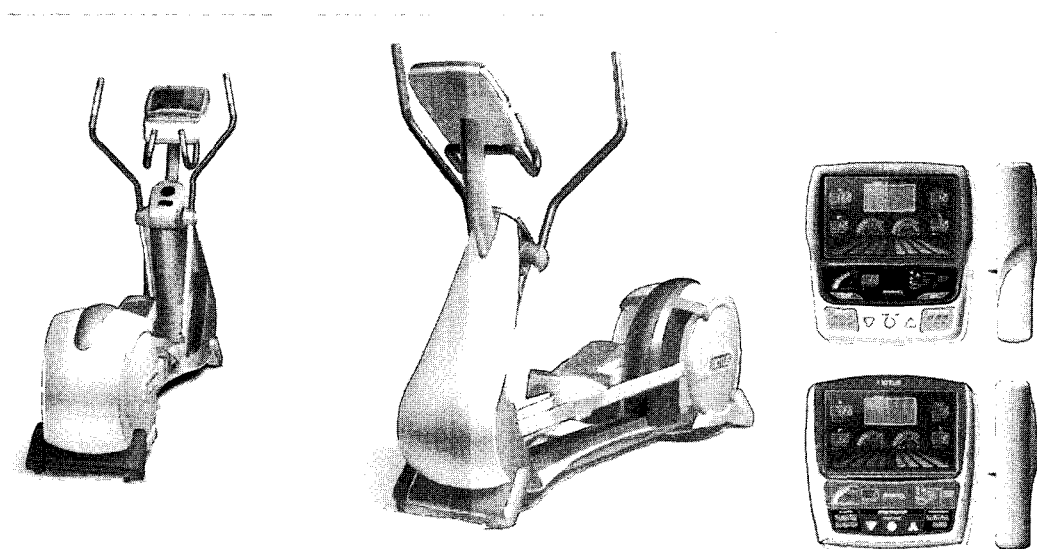


Fig.7 3D Rendering (References : UP Design Co.)

10. Conclusions

In the development of exercise equipment in Korea, the study and examination of its design have been treated with very little care compared to advanced countries. Such reality has lowered the design level

and market competitiveness of Korean made equipment. However, the exercise equipment development companies in Korea have recently focused a great deal of effort into design development considering that the design technology will be the 21st century core industrial technology that can achieve firm superiority in the market.

This paper introduced the process and results of the design-engineering cooperative R&D study for the development of effective and purpose achieving ECT design as a result of such efforts detailed above. The valuable experience and design development know-how obtained from each process have established the basis for taking active measures for the future demand in innovative exercise equipment design.

The development and possession of Korea's unique exercise equipment design technology will greatly contribute to the enhancement of national competitiveness in the overseas market and the improvement of life quality.

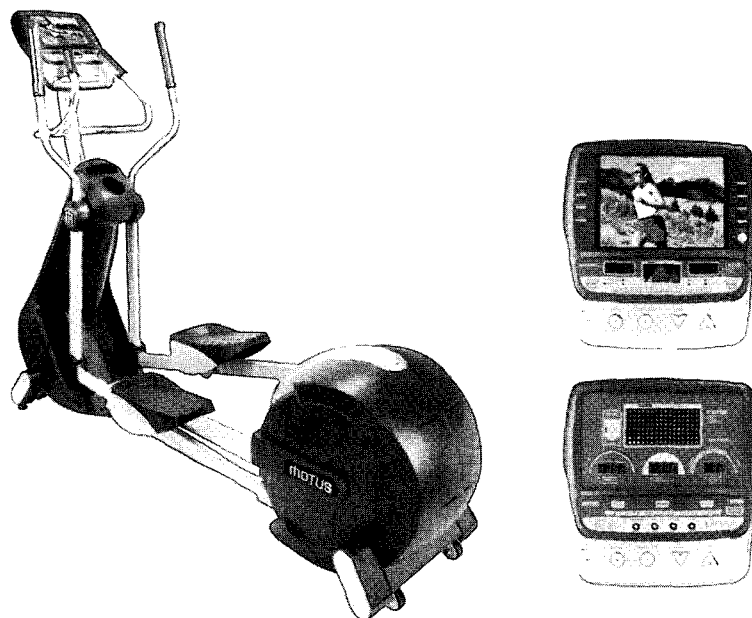


Fig.8 Final Model (M770EL of MOTUS Co.)

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