THE USE OF COMPUTER AIDED DESIGN (CATIA V5 R8) FOR ERGONOMICS ANALYSIS

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Abstract

Along with the increased use of computer-aided design (CAD), the computer-based ergonomics systems, which include graphical human models and computer-assisted workplace designs, play an important role in the process of incorporating ergonomics knowledge about human characteristics into the design process.

CATIA V5 R8 is a CAD program which is featured with human modelling and ergonomics analysis capabilities. This software has been extensively used for feature-based part design, mechanical assemblies design, and drawing generation. However, the human modelling and ergonomics analysis features in this software may have not been widely recognized and applied by designer in the design process.

This paper is concerned with the study of Ergonomics Design and Analysis workbench in CATIA V5 R8 and the exploration of capabilities of this software for human modelling and ergonomics analysis, and simultaneously highlight the importance of ergonomics considerations in the design process. The study is developed through a series of case studies, which involves the use of four main options in Ergonomics Design and Analysis workbench, namely Human Builder, Human Activity Analysis, Human Posture Analysis, and Human Measurements Editor.

In the last part of this paper, the capabilities of CATIA V5 R8 in human modelling and ergonomics analysis, including its advantages and disadvantages, are evaluated. Some related issues regarding the use of computer-aided ergonomics are discussed as well.

Keywords: *CAD, human modelling, human builder, human activity analysis, human posture analysis, human measurement editor.*

1. Introduction

With the latest development of computers, ergonomists and other professionals in human factor fields have acknowledged the need to develop ergonomics software and other computer-aided tools that enable the specialized expertise in ergonomics fields to be accessed in a suitable form by practitioners. As the visualization and engineering functions of a design are now increasingly performed with digital prototypes or mock-ups displayed on computer graphic terminals (CAD/CAM systems), the need to provide computer-based ergonomics assessment function as well is unquestionable. This is because the system can be used, in conjunction with the model of the product being designed from the CAD system, to carry out user trials for assessing criteria such as reach, fit, vision, and posture. Such predictions encourage the ergonomists to be more proactive in the design process and to be able to work closely with the other design team members to achieve ergonomics solutions to the design within various constraints from the other fields.

With computer-aided ergonomics systems, the designers can now more effortlessly gain ergonomics feedback required in designing products or workplaces for human use already at the design phase, when the cost of design modifications is relatively low. By incorporating the ergonomics knowledge through the use of ergonomics software at early design stages, the manufacturer is able to bring a product to market with a minimum number of prototypes, lower cost, and better fit for the user (Jarvinen & Lu 1999). Figure 1 presents a simplified product design cycle and the ergonomics evaluation phases in that cycle.

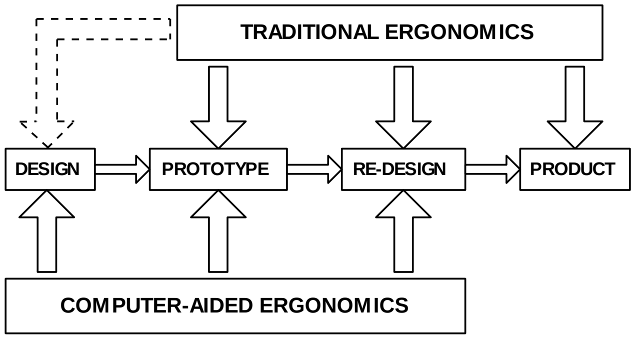


Figure 1. Ergonomics analyses in the design process
(Redrawn from Leppanen & Kuusisto 1992, p.153)

New software applications in the field of ergonomics are being developed at an accelerating pace. At the first time, ergonomics software was based on geometric human models (computerized human modelling system. Recently, a variety of analysis modules and databases have been integrated into these human modelling systems. Other ergonomics software that is currently available includes ergonomics analysis programs (e.g. biomechanical analysis) and computerized database programs (Jarvinen & Lu 1999).

Related to the design system, practically, there are two types of human modelling systems. One is a modular component or an element of a general design program (CAD software), and the other is an independent or stand-alone human modelling system. Both types have advantages and disadvantages (Launis & Lehtela 1992).

2. Problem Statement

CATIA Version 5 Release 8 is one of the available computer-aided design software, which has been use extensively in feature-based part design, mechanical assemblies design and drawing generation. With CATIA, various products, from aeroplanes, cars, to small product's parts can be designed and shown in the form of three-dimensional mock-up on a computer terminal.

Not only does CATIA V5 R8 has sophisticated and extensive capabilities in designing and drawing a product, it is also featured with human modelling and ergonomics analysis capabilities, which are modular components of the CAD program in this software. The existence of these features may motivate the users to use them for assessing the product or workplace being designed in the CAD program, so that the fitness for human use can be ensured early in the design phases.

However, the human modelling and ergonomics analysis features in CATIA V5 R8 may have not been widely recognized and applied by designers. Lack of ability in using such features, lack of comprehensive ergonomics knowledge, and ignorance of the importance of ergonomics evaluation in design can be the main reasons of this problem. In turn, these may lead the designers to further abandonment of ergonomics inputs in the design process.

This paper will introduce the Ergonomics Design and Analysis workbench in CATIA V5 R8, explore some of its capabilities in human modelling and ergonomics analysis, and highlight the importance of ergonomics considerations in the process of product and workplace designs. It is expected that this paper can broaden the reader's perspective about the use of computer-aided design/ergonomics – in this case CATIA V5 R8 – for analysing and solving ergonomics problems in the design process.

3. Scope and Methodology of the Paper

The study in this paper includes four main parts of Ergonomics Design and Analysis workbench in CATIA V5 R8, which are Human Builder, Human Activity Analysis, Human Posture Analysis and Human Measurements Editor. For each part, a case study will be presented as example of the use of that part. These case studies do not involve complex and sophisticated problems, such as the evaluation of fitness, reach and vision of a car cabin, or complex interactions between manikin (human model) and product, although CATIA V5 R8 is capable of doing such.

The last part of this paper presents some analysis and discussions about the application of CATIA V5 R8 to ergonomics problems, which include the strong points and the limitations of Ergonomics Design and Analysis workbench in CATIA.

4. Ergonomics Design and Analysis Workbench in CATIA V5 R8

CATIA V5 R8 as a CAD system is featured with human modelling and ergonomics analysis capabilities. Hence, the product being designed in the Part Design workbench can directly be evaluated for user's fit based on ergonomics criteria. These features are contained in Ergonomics Design & Analysis workbench, which consists of four main parts, namely Human Builder, Human Activity Analysis, Human Posture Analysis and Human Measurements Editor. Further explanations of the four options in Ergonomics Design and Analysis workbench are given below (Dassault Systemes 2002):

4.1 Human Builder

Human Builder provides very accurate simulation of humans and their interactions with products or environments to ensure they will work safely and comfortably in a workplace designed for their tasks. The Human Builder product is mainly concerned in creating and manipulating digital humans for human-product interaction analysis.

With a few mouse clicks, Human Builder is able to create anthropometrically accurate, three-dimensional human models representing several ethnic groups and percentiles. These models can be manipulated to any human-compatible position and viewed from any angle, distance, or perspective.

Some tools contained within the Human Builder are manikin generation, gender specification, percentile specification, direct and inverse kinematics manipulation techniques, animation generation, monocular, binocular and ambinocular vision simulations, and vision output cones.

(a) (b)

Figure 2. (a) New Manikin dialog box (b) Manikin in a standing posture

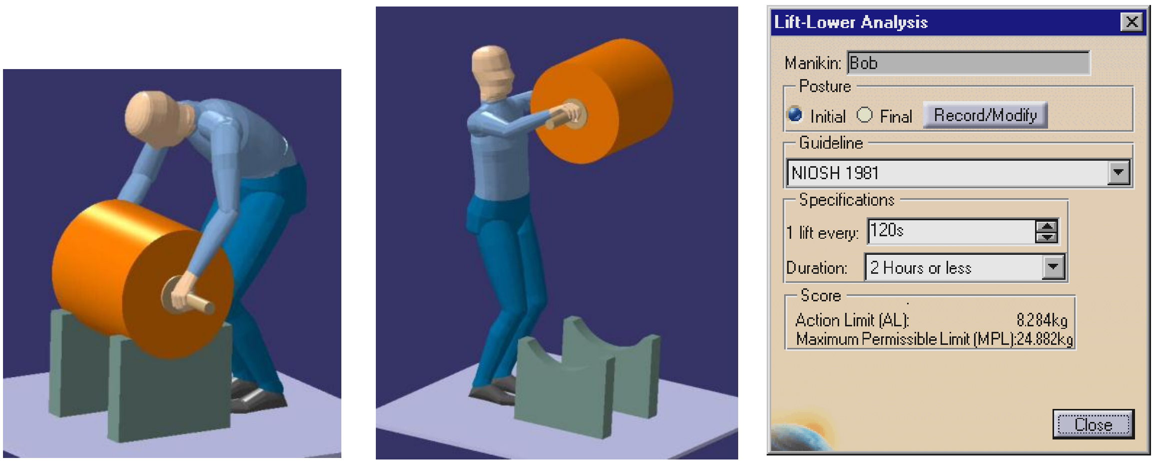
The human model (manikin) is created by inputting desired characteristics into *New Manikin* dialog box (see figure 2a). Figure 2b shows an example of manikin representing an American man with 50^{th} percentile in standing posture. This human model can be manipulated to create various postures by using *direct* and *kinematics manipulation techniques* or automatic features such as *Posture Editor* and *Standard Pose*.

4.2 Human Activity Analysis

Human Activity Analysis specifically focuses on how human will interact with objects in a workplace. It also analyses the effects of lifting, lowering, pushing, pulling and carrying on task performance.

Human Activity Analysis assesses all elements of human performance from static posture analysis to complex task activities. A range of tools and methods are provided to specifically analyse the interaction between human and objects in the virtual environment. The analysis of working postures in the workplace includes RULA (Rapid Upper Limb Assessment) analysis for investigating the exposure of individual workers to risks associated with work-related upper limb disorders, lift/lower analysis (based on NIOSH 1981, NIOSH 1991, and Snook & Ciriello equations), push/pull analysis (Snook & Ciriello), and carry analysis (Snook & Ciriello). These analyses are used to optimise task performance. The users can determine a number of task variables such as action limit, maximum permissible limit, recommended weight limit, and lifting index. Human Activity Analysis allows the users to accurately predict human performance, ensure conformance to health and safety standards, as well as maximize human comfort and safety.

To show the application of Human Activity Analysis option, a lifting task case as follows will be used (adapted from Chaffin 1985): an American worker (male) with 75^{th} percentile has a task to lift a stock reel weighing 20 kg into a punch press. The worker services 10 punch press machines which require a new stock reel every 15 minutes in 8 hours work period. The initial lift begins at a vertical height (V_i) of 550 mm above the floor with the hands about 530 mm from the worker's centre of gravity (H_i). The vertical height of destination location (V_f) is approximately 1600 mm. The work condition will be evaluated based on NIOSH 1981 guideline by determining the Action Limit (AL) and Maximum Permissible Limit (MPL).



(a) (b) (c)

Figure 3. (a) Initial lifting posture, (b) Final lifting posture, (c) Lift-lower Analysis dialog box

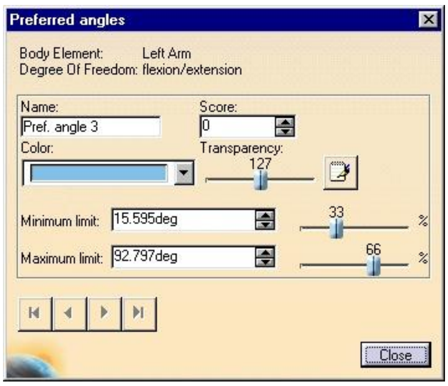
Two postures are required for solving the problem, i.e. initial lifting posture and final lifting posture. Some environments such as floor, punch press machine, and stock reel may be necessary as well. Figure 3a and 3b respectively illustrate manikins with the given characteristics in initial posture and final posture. The position of each body segment of the manikins and related environments are arranged such that they conform the described work condition. The postures are then recorded together with guideline type, lifting frequency, and work duration. The values of AL and MPL are presented in *Lift-Lower Analysis* dialog box (see figure 3c).

4.3 Human Posture Analysis

Human Posture Analysis is concerned on how human posture can affect job performance by analysing local and global postures, preferred angles and comfort.

The users are allowed to analyse all aspects of human model posture quantitatively and qualitatively. Whole body and localized postures can be examined, iterated, scored, and optimised to determine operator comfort and performance throughout the complete range of task motion based on published comfort databases. Problem areas can be quickly identified and iterated to optimise posture by using colour-coding technique. Human Posture Analysis also permits the users to create specific comfort and strength libraries to meet the needs of individual applications.

As an example, we will set and edit preferred angles for driving posture based on pre-established comfort angles and scores. First, a manikin is created in driving posture (see figure 4a), and then for each body segment of the manikin, preferred angles with their scores and colour codes (eg. green is optimal region with score 10, yellow is acceptable region with score 5, and red is unfeasible region with score 0) are set through *Preferred Angles* dialog box (see figure 4b). Figure 5 shows the preferred angles with coloured regions on manikin's left thigh and left arm. Having the edited preferred angles, any manikin's driving posture can now be evaluated and optimised by using *Postural Score Analysis.*



(a) (b)

Figure 4. (a) A manikin in driving posture, (b) Preferred Angles dialog box

4.4 Human Measurements Editor

The focus of Human Measurements Editor is on creating anthropometrically detailed digital humans for advanced ergonomics analysis and global target audience accommodation.

Human Measurements Editor provides anthropometric data from five default populations (American, Canadian, French, Japanese, and Korean). These data are used for creating five default human models. However, the users can create any human being from any population in the world by adding user-defined population databases.

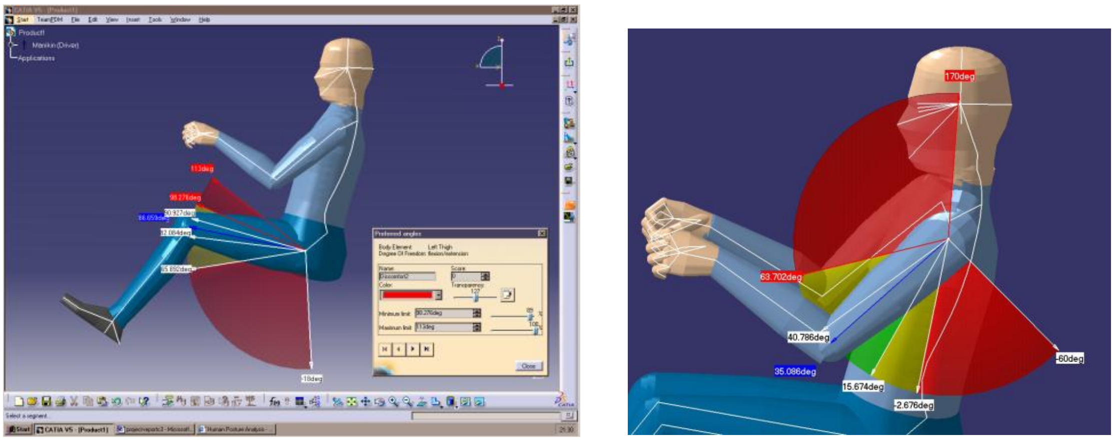
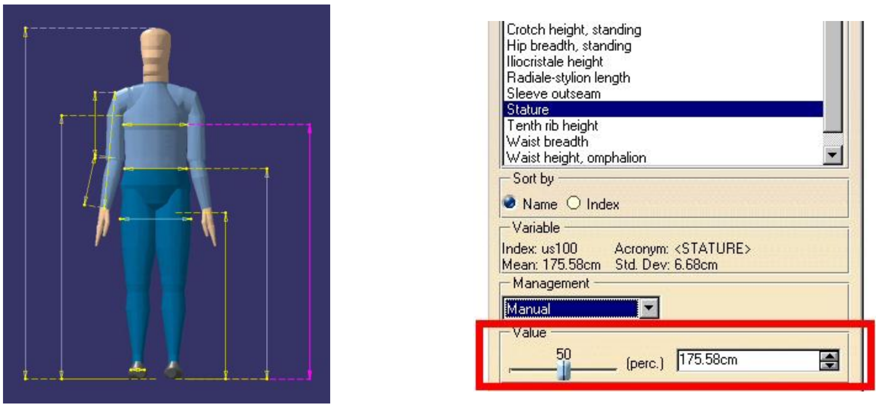


Figure 5. The preferred angles with coloured regions on manikin's left thigh and left arm

The human models can be shown in different postures (standing, sitting, reaching, etc.) and different point of views, along with the related anthropometric variables on them. The users can modify all 103 anthropometric variables on the model or manipulate only several "critical" variables and the Human Measurements Editor will determine the rest. These variables can be changed manually by inputting desired measurements in unit measurement, percentile value, or by an intuitive "click and drag" graphical user interface (variable edition by arrow management). This enables the users to create various types of human body (the so called *somatotype*).



(a) (b)

Figure 7. (a) Anthropometric variables on manikin, (b) Variable Edition dialog box

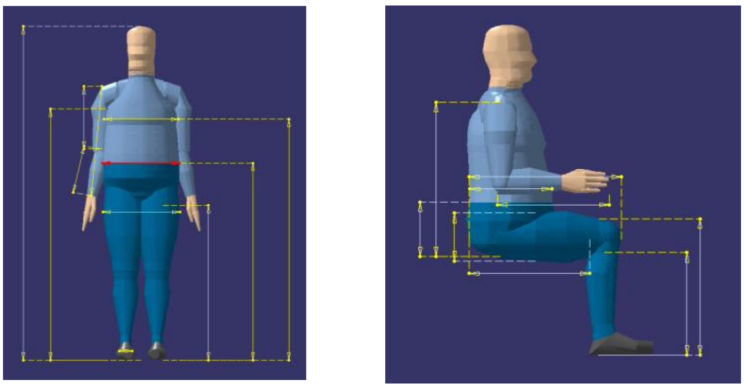


Figure 8. A manikin of fat man as a result of waist breadth modification

Figure 7a presents a manikin of 50th percentile Canadian man, completed with its anthropometric variables. Any of those anthropometric variables can be modified by directly click and drag the red arrow in the viewer, or by using manual method through *Variable Edition* dialog box (see figure 7b). For example, the manikin's waist breadth will be modified to create a fat man. Once the waist breadth is changed, CATIA automatically updates the other anthropometric variables in order to avoid inconsistency and to ensure the created manikin will realistically exist in the target population. The result can be seen in figure 8.

5. Analysis and Discussion

Porter et al. (1999), Launis & Lehtela (1990, 1992) proposed several features and criteria for examining the differences between computerized human models and ergonomics design tools. Based on those criteria, the human modelling system in CATIA V5 R8 can be described as follows:

- CATIA offers a sophisticated 3D human model, which comprises many body segments and more than 60 articulated joints, including detailed models of the hands and spine. The visualization is excellent and realistic.
- The movement range of the manikin's joints is constrained to possible angles so that the construction of impossible postures can be avoided. The user can also modify the upper and lower limit of this movement.
- CATIA provides anthropometric measurement databases, consisting of five populations (American, Canadian, French, Japanese and Korean). The system enables the user to incorporate user-defined anthropometric databases into the program as well.
- The size of individual body segments can be modified manually, and the size of other segments will automatically be updated by the software to ensure that the human model realistically exists.
- Ergonomics Design and Analysis workbench is an integrated element of the CAD system in CATIA. Therefore the human model does not have to be ported to and from another CAD system. Thus, it adds convenience for the designers.
- CATIA can be applied to various ergonomics problems and new situations, including accurate human modelling, human activity analysis (lifting/lowering, pushing/pulling, carrying), human postural analysis (comfort angles), human dimensioning, vision analysis, and so on.
- By using the human and workplace models generated by CATIA, a designer can visually assess the human model's reach, fit, or vision.
- The human modelling system and ergonomics features in CATIA are relatively user-friendly and easy to use.
- The manikin is easy to manipulate by means of direct (forward) kinematics, inverse kinematics (auto reach), standard pose editor, and human posture editor.

It seems that the human modelling system in CATIA V5 R8 emphasizes the visualization of its human model by developing a very convincing model with complex, fully articulated joints, and surface modelling. Subsequently, a wide range of human postures can be realistically constructed and used in conjunction with product being designed for reach and fit assessment. A number of well-known work analysis methods, such as NIOSH 1981/1991 lifting equation, RULA analysis, and Snook & Ciriello equation, are incorporated for allowing the software to conduct some ergonomics analysis upon a certain job condition. However, CATIA V5 R8 is not greatly concerned with biomechanical analysis that is usually included in independent ergonomics software such as MQPro, JACK, ErgoSHAPE, ErgoMOST, and SAFEWORK. CATIA V5 R8 is not capable of providing/calculating moments, compression forces, or torques load on selected joints, especially on the L5/S1 lumbar disc, which is very important in analysing ergonomics stress and injury risk of a certain work method. It does not provide strength data as well.

By using human modelling and ergonomics analysis features in CATIA, it does not mean that ergonomics solution in the design process will be created automatically based on a set of specified inputs. CATIA should be regarded as a tool to be used by the designers for evaluating workplace, product, or work method design, where the software can help the designers to quickly identify the source of ergonomics problem, enabling them to concentrate on the solution rather than the problem.

Furthermore, it is important to remember that the quality of the results and recommendations from CATIA are highly dependent on the validity, accuracy, and completeness of the information inputted by the user. If the true problem characteristics are not accurately represented in the input data, the results of the analysis will not be valid. Consequently, any recommendation that is given may be very inappropriate.

In the end, the designer should be aware that human models in a computer system do what the designer instructs them to do, however the real people or the end-users of the product being designed, particularly when poorly trained, under stress, fatigue, and so on, are unlikely to be quite so obliging (Porter 1992; Porter et al. 1999).

6. Conclusions

Without a doubt, the Ergonomics Design and Analysis workbench in CATIA V5 R8 is an advanced human modelling and ergonomics analysis system which contains a great many sophisticated features and capabilities. Nonetheless, since it is an extension feature of the CAD system, there are still some limitations compared to the independent ergonomics programs that are fully intended for analysis, assessment, and evaluation in ergonomics fields.

It is essential to appreciate that the quality of ergonomics software has more to do with the assessment of the design team and ability to integrate pronounced ergonomics principles in the design, rather than to the sophistication or the features it has.

7. References

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