

# APPLICATION OF DATA GLOVE FOR ASSEMBLY ANALYSIS OF SELECTED COMPONENT

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The aim of this work is to analyze the assembly of selected component using Cyber Glove II data glove and CATIA V5 program using Rapid Upper Limb Assessment analysis (RULA). The RULA analysis is mainly used in the evaluation of work positions performed by workers in manual work such as assembly and disassembly. The RULA analysis assesses the individual states of posture, strength and muscle activity that have been proven to contribute to re-stressing the spine. The continuous advancement of computer technology also causes its participation in other industries. The purpose of this work is to analyze the selected assembly process in virtual reality, CAD program and using data gloves to capture process trajectories and propose corrective action using RULA analysis, which will eliminate shortcomings resulting from the previous state.

## KEYWORDS

Manual assembly, process analysis, CAD program, virtual reality, RULA analysis, CATIA, data glove

## 1 INTRODUCTION

If we consider the importance and position of the assembly in the production process, it is necessary to know that in the engineering production process, 28 to 41% of the total production effort of the product falls on the assembly work. On average, manual work accounts for 34%, mechanized assembly 64% and automated assembly only 2.3%. The area of assembly is one of the least developed areas with a high share of manual labor. Today, the assembly industry is less developed than other industries, especially because of its complexity and product specificity. This implies the need to pay more attention to the development of assembly processes. The application of rationalization strategies in individual industries brings different results. One of the basic rationalization strategies applied in all sectors is product design. Product design achieves installation time savings (11.5 - 21.5%). By mechanization and automation, time savings of 19.5% are achieved in the electrical industry and in the manufacture of precision tools. Rationalizing assembly cannot depend on a particular strategy or technology itself. Different achievable rationalization strategies have to be

examined and evaluated, in particular as regards the analysis of cost-effectiveness for industry-specific production factors. In applying the principles of complete automation of production processes, the tendency to the share of assembly effort increases, resulting in the overall production effort of the product. There is a need for modular, multi-purpose and flexible assembly equipment. Currently, the trend is to deploy robots in industries. The analyses show that the assembly process will be the area most represented by the number of industrial deployed robots [Legat 2008], [Daneshjo 2012].

## 2 ANALYSIS OF ASSEMBLY PROCESS USING DATA GLOVES

Analysis of assembly operations was done by scanning the right-hand trajectory. Since the technical means are a part of the work, it was necessary to get acquainted with them and to describe the individual components of the whole system. To work with the data glove was used a workstation which is located in the laboratory of virtual reality at the Technical University in Kosice [Seminsky 2015]. The workstation consists of a desktop computer with software installed for virtual reality (Catia V5 R15, Device Utility, Device Configuration Manager V5R15, VirtualHand). The Tackle, Flock of Birds and Cyber Glove II is part of the workplace. This workplace is shown in Fig. 1. The above picture shows two trekking gear and two gloves. Only the trekking device and the right-hand data glove were used in the analysis. The assembly itself took place at the assembly workplace in the laboratory.



Figure 1: A virtual reality workstation [27]

### 2.1 DATA GLOVE CYBER GLOW II

The virtual reality lab is equipped with a pair of Cyber Glove II gloves that contain 18 sensors. For assembly analysis, due to the technical problem of connecting both gloves simultaneously, only the right glove was used to record trajectory movements. This glove is shown in Fig. 2.



Figure 2: Data Glove Cyber Glow II

The Cyber Glove II wireless glove captures movement, incorporating 18 high-speed and accurate measurement

sensors. It uses resistive technology that is patented to accurately transform hand and finger movements into real-time data.

## 2.2 FLOCK OF BIRDS

Ascension Technologies' trekking equipment uses magnetic sensing technology. Flock of Birds can be connected to a computer via the RS-232 interface. This device can only be used to sense the position of one glove. To scan two gloves, it is necessary to connect two trekking devices which simultaneously use one emitter. Fig. 3 and Fig. 4 show the connection of the Flock of Birds for one glove. 4. This equipment was also used for analysis [Senderska 2017].

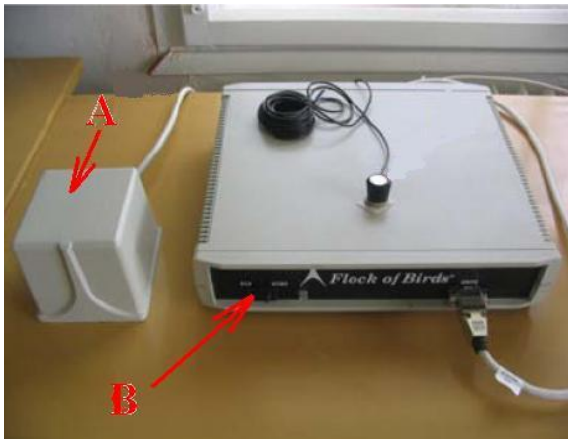


Figure 3: Emitter (A), Flock of Birds (B)



Figure 4: Motion sensor (B)

## 3 ASSEMBLY SITES

For the purposes of paper, the assembly workplace (Fig. 5) which is located in the laboratory, was chosen. At this point, all the assembly-related activities for the analysis were performed. The KIA Motors 1.6 CRDi engine which is mounted on a mobile stand, served as a model. Two handling tables were attached to the workplace to hold the tools and screws needed for assembly and the lid itself. We have added a scanning device and a computer to the workstation which then processed the data from the Cyber Glow II [Evin 2012], [Petroci 2017].



Figure 5: Assembly sites

## 4 MODEL OF VIRTUAL MAN

Choosing a virtual human model is an important factor for the proper optimization of the assembly site. We create this virtual worker in Catia V5 in the Human Builder section (Start / Ergonomics Design & Analysis / Human Builder). The module contains the insert and new manikin icon [Malega 2007]. After clicking it opens the menu. Several basic parameters are determined. In the selection menu, there is a male or female gender [Daneshjo 2017]. The man is better suited for physically demanding assembly work and given the fact that I was performing the installation personally, we used a man as a virtual worker. It also takes into account where the installation will be carried out, which country, which continent and the representative of the population will be chosen accordingly [Senderska 2016].

For example Canadian has other anthropometric parameters like Korean, weight, height, working range, etc. Another factor is the percentile shown in Fig. 6 and can be selected from 0.01 to 99.99. Such a mounting site is proposed for a statistical sample of the population in that country and not for one particular worker. This will take into account the anthropometric dimensions of the people to the optimal extent. We used the percentile 50 in the work [Kovac 2012], [Kulka 2018].

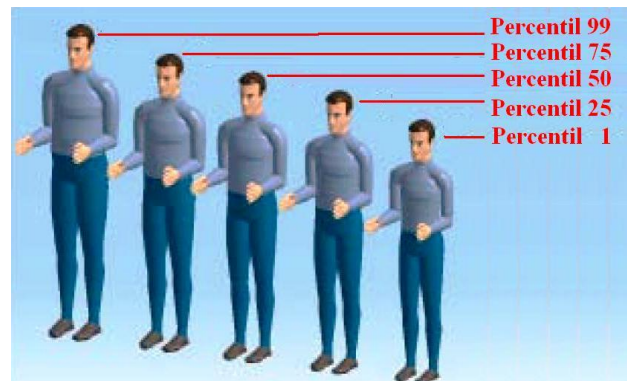


Figure 6: Percentiles

The menu also includes a menu with the option to select only a certain part of the body for analysis. As one of the assembly workstations, we can choose to select motion sensing between the right or left hand, respectively arm or analyze whole worker]. The last item in the menu is the reference point selection – reference. The basic parameters entry system is shown in the Fig. 7.

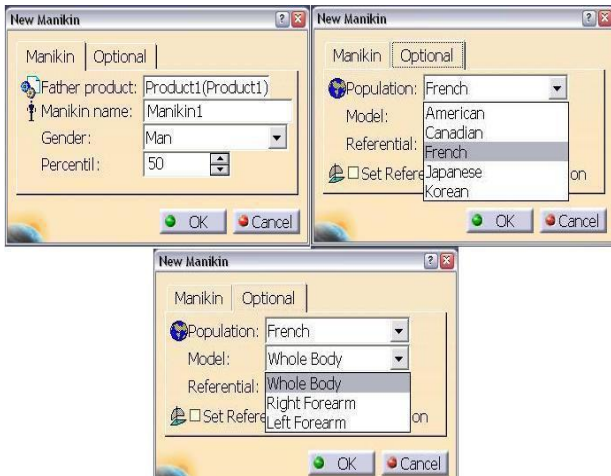


Figure 7: Basic parameters of entry system

After selecting all the parameters, it is possible to create a virtual workplace that also serves to illustrate the real state in real conditions

### 5 3D Model Of Workplace

In the 3D space, it was necessary to create an assembly workstation so that motion analysis could be done using the Cyber Glow II glove and make a RULA analysis. Since there are already various databases in which many 3D models are stored, it was not necessary to model all the parts like screws and in this particular case we did not have to model the injection nozzles either [Fabian 2015]. For a better ergonomic idea, we have created a mounting workplace to the exact dimensions as the engine is in the car and the worker stands in front of it. Other components or parts of the car would not be important in this case, as they do not contribute or hinder the better or worse assembly or removal of the cylinder head cover.

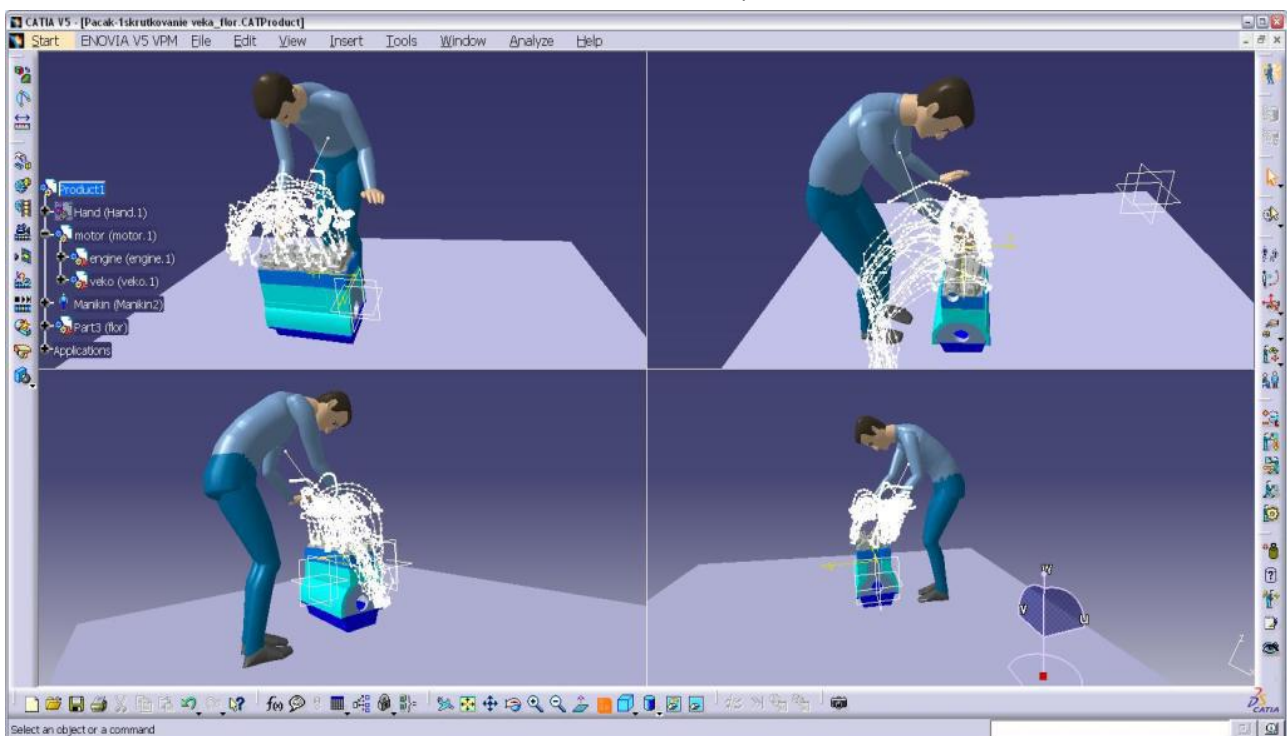


Figure 8: 3D model of workplace from different views

The function called Vision in Catia V5 serves us to display the assembly workplace from the worker's point of view. Fig. 9 shows such a view.

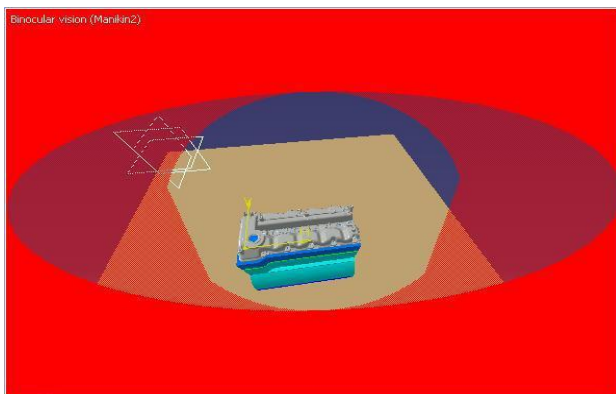


Figure 9: Function Vision – worker's point of view

### 6 THE PROCEDURE FOR CAPTURING TRAJECTORIES

Turning on the computer also turns on the Flock of Birds. Subsequently, the Cyber Glow II data glove is activated (the green diode on the glove will start flashing) via bluetooth will connect to the computer. Start Device Manager and Device Configurator Utility. After that, Flock of Birds and Glove are joint. Virtual Hand Catia is launched, and we open a new product (File > New > Product). Then we add the hand and set flexibility. The last step is to start the hand movement and record the trajectory (Digital Mockup > Start Recording > Start Manipulate). When the installation is complete, we stop recording and save the scanned data. This process allowed us to capture the trajectories that can be viewed when the product is reopened. The resulting scanned trajectories are shown in Fig. 10.

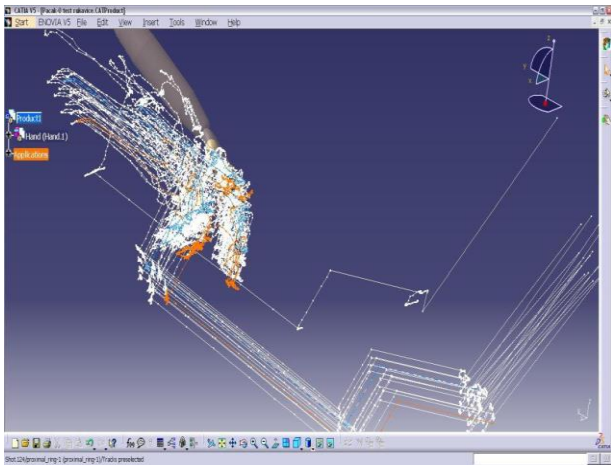


Figure 10: Taken trajectories in CATIA V5, in module Digital Mockup

When assembling in real environment and with real components, the operation of inserting and mounting the screws of the lid (Fig. 11) and their tightening by hand tools was realized (Fig. 12). This operation was recorded on the computer and then RULA analysis was made from this data. Using a data glove, these motion trajectories have been created and applied in 3D environments. When integrating the scanned trajectories, it is possible to rotate and move the individual elements in the assembly so that the resulting state corresponds to the actual state of real assembly.



Figure 11: Inserting M6 screws into the valve cover - real assembly



Figure 12: Tightening of M6 screws with hand tools - real assembly

After inserting the trajectory, engine models and valve lids, the virtual worker of Figure 13, it is possible to perform an ergonomic analysis of the individual body parts. In this thesis RULA analysis was performed.

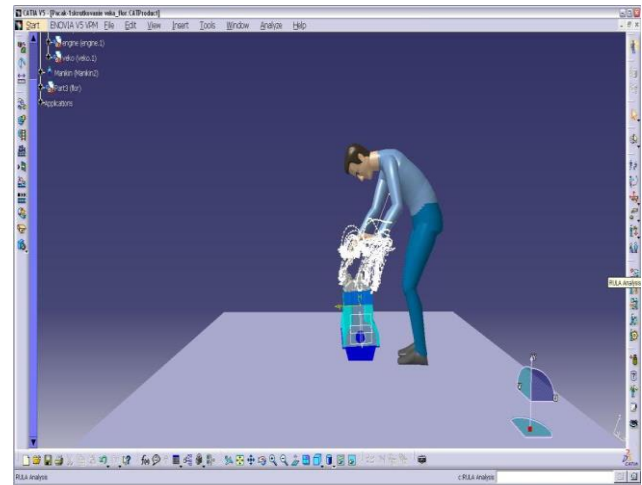


Figure 13: Representation of trajectories in the valve lid assembly process

## 7 RULA ANALYSIS

This analysis was designed to eliminate the strenuous actions of sitting or standing workers. It is based on input data which form exact positions of body parts (head, back and hands), used forces, types of movements, repeatability of these activities and anthropometric properties of the user. Each part of the body is examined as a separate quantity and, depending on the actions being performed, a point evaluation of the effort generated is assigned to the area. The main use is in examining the ergonomics of operating machines, equipment or workplaces.

RULA analysis is characterized by these features:

- It takes into account a number of factors, such as the weight and size of the object, the handling distance, repetition frequency, assembly duration, etc.
- It offers the ability to determine the specific performance characteristics of a given assembly task, for example, whether the user has external support for the body or hands, they pass through the body axis during operations, and whether the user is stable or balancing.
- It creates a comprehensive report on the given installation task, where each part of the body is evaluated separately.
- It is clear from the scoring of individual parts of the body whether the assembly operation is optimal, whether optimization would be appropriate or the optimization is needed to be performed immediately.

The settings for these analyses are shown in the dialog boxes from Fig. 14 to Fig. 15. A description of the meaning of each item is shown in the following figures.

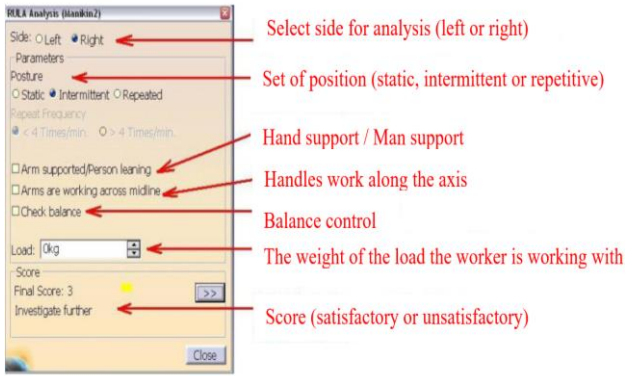


Figure 14: Main dialog for RULA analysis

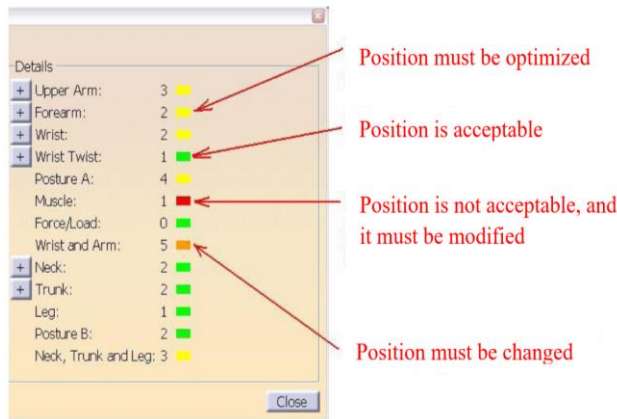


Figure 15: Main dialog for RULA analysis

The evaluation of individual body parts is shown in Tab.1. The overall ergonomic characteristics of a virtual worker are evaluated by matching numerical and color markings.

Part of body	Score	Color rating					
		1	2	3	4	5	6
Upper hand	1 – 6	Green	Green	Yellow	Yellow	Red	Red
Lower hand	1 – 3	Green	Yellow	Red	Grey	Grey	Grey
Carpus	1 – 4	Green	Yellow	Red	Red	Grey	Grey
Spin of Carpus	1 – 2	Green	Red	Grey	Grey	Grey	Grey
Neck	1 – 6	Green	Green	Yellow	Yellow	Red	Red
Body	1 – 6	Green	Green	Yellow	Yellow	Red	Red

Table 1: Rating of RULA

By applying of the RULA analysis we can revealed which parts of the body were most stressed. In the following figures, Fig. 16, Fig. 17 and Fig. 18 is the load of both the torso, neck and upper and lower limbs during assembly. The right side of the dummy was used for analysis and as reference. Since it was not possible to work with both gloves at the same time in virtual reality. The resulting rating for this assembly had a score of from 6 to 7. The score did not improve even after a slight correction (animation 2 and 3). Such a score is unsatisfactory and needs to be immediately improved to a satisfactory value that is in the range of 1 to 2 resulting from Tab.1. Mounting other components such as injection nozzles or motor accessories such as cabling, brackets, would certainly be the same, if not

worse, as the resulting score depends on the aforementioned factors such as the weight of the load, repeatability of the action, and so on.



Figure 16: RULA analysis - unsatisfactory condition for installing the valve cover (animation 1)

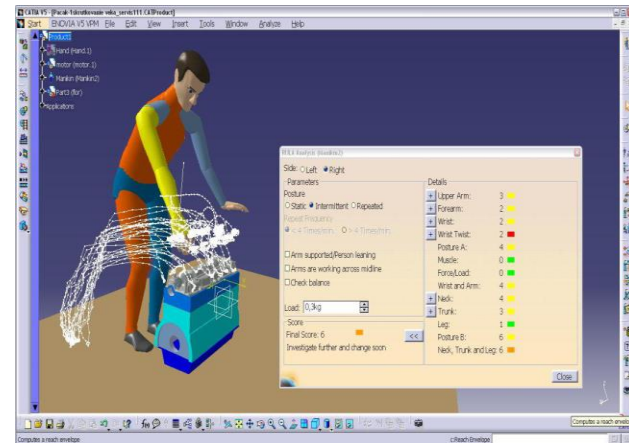


Figure 17: RULA analysis - unsatisfactory condition for installing the valve cover (animation 2)

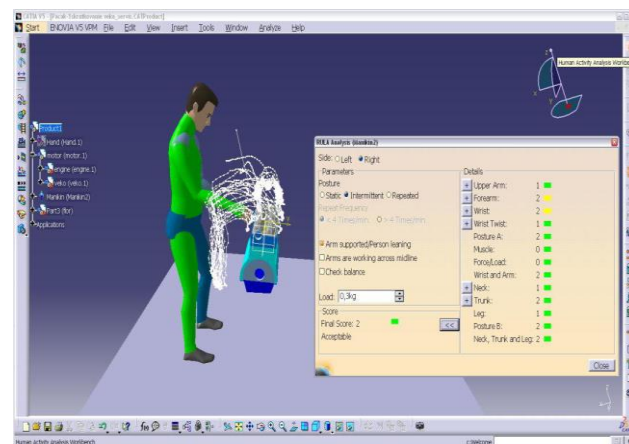


Figure 18: RULA analysis - satisfactory condition for installing the valve cover (animation 2)

The resulting unsatisfactory condition is subject to the design of possible measures to improve the worker's job position in performing the assembly process. This result was due to the fact that the mounting area was in the base position which is actually the state of the vehicle on the wheels. The prerequisite is to achieve a satisfactory condition during assembly, which

results from the next RULA analysis. External aids or devices can also help with this.

The repeated RULA analysis after inserting new data and data suggests that the use of an external jack and a 30 cm lift had its justification, which resulted in a positive result. In this case, we can say that the assembly worker has only a minimal amount of weight. However, certain parts of the body are still slightly more stressed than others, namely forearms and wrists, which should be further analyzed and optimized but this is within the tolerance of moderate loads. It is important to note that the ideal situation is not very realistic.

## 8 CONCLUSIONS

The use of CAD software support – that is augmented by virtual reality resources – has its place in the automotive industry rightly. Such cooperation results in workplaces that take into account all ergonomic requirements. The assembly workstations designed in this way reduce worker fatigue. They also help to reduce staff turnover and thus reduce the cost of retraining new workers. The efficiency of the production system is increasing.

The topic of this work was to optimize the assembly workplace based on the analysis of the assembly using data gloves and RULA analysis. The RULA analysis showed an unsuitable location of the assembly workplace, where excessive stress was exerted on the worker's body. The proposed measure found that the equipment used helped the installer to improve the assembly process, as evidenced by the result of the RULA analysis. Thus, the workplace designed with regard to the results of the analysis meets all the requirements of ergonomics.

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