FCA Ergonomics approach in developing new cars: virtual simulations and physical validation.

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Cars' manufacturing is undergone radical changes because of market continuous request of new models developed in fewer and fewer years. Original Equipment Manufacturer and suppliers have to develop more flexible and adaptive assembly chains, manufacturing services and methods for job planning. The requirements of today's process management, such as high standard of efficiency, quality, safety and ergonomics, are achieved by enforcing detailed models of work processes and to assume a change of mind in process design and in new production system applying a human centered approach in manual assembly tasks. In Fiat Chrysler Automobiles, this new approach starts using the virtual simulation “Digital Manufacturing” and immersive 3D virtual reality in the design phase. Virtual simulations allow to create different scenarios to carry on an assembly task and to make improvements and changes almost without any costs. Different scenarios, coming from simulation step, are evaluated, from different points of view, by a working team of occupational doctors, designers, ergonomics specialist and blue collars. Moreover, data and information, coming from simulations, regarding critical issues such as reachability, visibility and incongruous postures engaged by operators or anomalous application of forces have to be validate in physical assessment. In fact, virtual simulations give as output the behavior of a static mannequin and, of course, it does not take into account the versatility and adaptability of 'flesh and blood' operator that often optimized postures and task performance. The physical assessment on prototypes runs in order to have a concreter idea of operator behavior and eventually his optimization of task; more over it allows blue collars to choose the better solution among the proposed ones. To maximize the physical assessment effectiveness, simulations were performed in an ergonomics laboratory were all facilities of assembly line are duplicated. In this way line space and working conditions are available and simulations were performed without interfering with plant's activities.

In this paper, a case study of this approach will be presented. A detailed description of two different scenarios coming from the virtual simulation, in design phase, will be given together with the physical assessment carried out with blue collars to choose the better solution in the task execution. The task implies ergonomics criticism because of the complexity of the tasks and the high quality and esthetics requirements.

1.1 Second-level Heading (Arial 10-point, flush with margin, italics, bold, line spacing 1.5)

1. Introduction

During the last years, the global car market has undergone to radical change, becoming more competitive and unstable due to several factors (legal, financial, environmental, etc.) so that the most important
automotive OEM have been obliged to react to this scenario. The continuous request to produce different new models in few years oblige OEM to develop more flexible assembly lines and better methods for job planning on the same lines. In the meantime, safety norms and product quality reasons request to improve working condition also according to international standards. More over assembly line is seeing increased levels of robotics and hybrid human-automation decision making and this requires new concepts for process design and for production: the human centered approach to improve manual assembly operations even assisted by automation. Therefore Ergonomics and work organization concepts have received a very strong development and new organizational models have been created using ergonomics guideline to organize and optimize production in the plants. Very important examples in these area are World Class Manufacturing (WCM) for production theories and European Assembly Worksheet (EAWS) for ergonomics and work organization (Ergo-UAS). These concepts allow to achieve the most important benefits only when they can be applied in the design phase of a new car’s manufacturing process because, in this case, the whole production system can be changed and optimized. For this reason, FCA has created the “Digital Manufacturing” team project whose final goal is to create simulation tool and procedure that allow to apply ergonomics principles and work organization methods in the early phases of a new project development for all manual assembly operations. In order to show how to achieve this result, it important to remember that, generally speaking, ergonomic analyses aim to improve different aspects of the manual work: postures, forces, manual material handling, etc. The DM approach has been based on the process to adapt these ergonomics methods to the “virtual plant” environment in order to get, already in the design phase, an high correlation between results obtained by the virtual simulation with those obtained on the physical analysis of the work tasks. Thanks to this process, it becomes possible to use ergonomic risk assessment indices already in design phase in order to change and improve project solutions and to well balance the work load between workers. Moreover the use of immersive reality allows to have an effective idea of visibility and reachability aspects. However, virtual simulations do not always allow the solution of all the typical problems related to workstation design because experimental data and physical validations on real components are necessary (for example to evaluate forces, flexible objects behaviors, etc). For this reason, FCA set up an Ergonomics Laboratory for experimental data evaluation. In these labs, tools and equipment as well as assembly methods are tested and measured using the most updated systems commercially available to study physical factors influencing ergonomics, quality and efficiency of manufacturing process. Through advanced instruments and specific methodologies of analysis, detailed data are measured and gathered. The big amount of information is then analyzed and validated by field test in order to frozen final design solutions.

2. Digital manufacturing

One of the most important aspects of the DM project, is the information’s “active management” that allows designers and engineers to make detailed virtual simulations in order to improve the car’s manufacturing
process. This concept has requested an important development on the methods used by FCA Manufacturing Engineering to manage all the information related to the production process: technological data are available in an unique simulation environment that contains virtual models of the car components and of the production plant (robots, tools, equipment, etc.). The key factor to improve DM simulations has been to insert digital human models and “human centred” simulation methods in the virtual environment in order to perform certified simulations for all the manual operations that are designed for the production process in the future plant.

![Figure 1: A virtual model of a production plant.](image1)

Digital Human Models are nowadays a standard in simulations software and many commercial products, like “Jack” by Siemens, are available on the market (Stephens, 2006). The Digital Manufacturing allows to create a virtual plant where virtual mannequins interact with digital models of car’s components, equipment, containers, etc. in order to simulate and improve working conditions with many benefits on ergonomics, safety, final product quality, work organization and general production costs.

![Figure 2: An example of assembly tasks.](image2)
3. **3D immersive virtual reality**

Mathematics of object can be used to create a 3D image of car and components. The operator wearing adequate glasses can be set in the immersive environment and interact to objects and tools. This system enables operators and designers to simulate all assembly operations, giving a realistic perception of size and space. In this way it is possible to highlight critical issues related to visibility and accessibility at the working point, while ergonomics specialists can check the possible risks related to the workstation directly with the operator or using the information provided by the dummy virtual system.

![Image](image.jpg)

**Figure 3:** An example of a working team using 3d immersive reality and an operator using the system.

4. **Ergonomics method**

The fundamental development on which FCA has based the Digital Manufacturing project for human simulations, has been the effort to improve standard digital human modeling software in order to let them be compliant to FGA’s design standards (based on international technical norms - ISO/EN norms -) and FGA’s production standards that are based on European/Italian legal specifications on safety and ergonomics. In this way, designers have not only a virtual representation of the future plant but also the virtual tools to validate design solutions. Reference frames on these mannequins have been created in order to have specific points on which evaluate body angles, distances, etc. according to the most important ergonomics methods requested by ISO/EN standards (ISO 11226) and by FGA’s standards (like OCRA NIOSH, Snook&Ciriello, EAWS).

EAWS especially is the ergonomics risk assessment method applied in design phase as an ergonomic screening tool. It links corrective and proactive ergonomics, points out ergonomic problems and offers design solutions to overcome them. The EAWS consists of four sections for the evaluation of
• working postures and movements with low additional physical efforts
• action forces of the whole body or hand-finger system,
• manual materials handling and
• repetitive loads of the upper limbs.

Figure 4: EAWS structure and sections (pp. 1–2).

Figure 5: EAWS structure and sections (pp. 3–4).

The evaluation, of mechanical load request by the workplace (considering product and process together) also in design phase, has to be carried out by the measurement of some physical parameters on prototypes or similar models.

5. Physical assessment
To assess physical parameters used in ergonomics risk assessment methods and tools choice was created at Mirafiori Plant, in the Manufacturing Engineering area the new ergonomic laboratory, ErgoLab. The main analysis conducted concerning postural aspects and efforts exerted by operators during working tasks as well as experimental measurement of physical parameters involved in equipment and tools use. In ErgoLab, the workplace of production units have recreated: Assembly and Painting are provided by car hook that can accommodate car models of different segments, Body in White is provided by welding system and a dedicated preparation workbench, Handling is provided by different container types, LCA systems and Ro-Ro; a mechanic workshop is provided by adaptive workbench to simulate preparation workstations. The
laboratory is grounded on the consistent experience gained over years from the collaboration with FCA Research Center, on different issues: the physical parameters measurement, the ergonomic design of workplace and, generally, the support during the design phase, selection and training in correct use of pieces of equipment according to national and international legislation requirements. The aim of ErgoLab creation is supporting plants, the Manufacturing Engineering area and designers with reliable information and data to design technological systems and ergonomic workstations. The main purpose is to make measurement procedures more accessible and to recreate working conditions without interfering with the working process. The main field of laboratory activities concern:

- measurement of force, localized and distributed pressure, reaction force couple, hand/tool interaction
- acceleration
- angles assumed by the main joints

All measurements focus on the physical characterization of the following three main areas: Tools, Equipments and Work methods. The acquisitions are made using the most advanced commercial instruments and sensors and the experimental procedures are well defined, documented and repeatable.

Figure 6: Examples of forces measurement.

Figure 7: Examples of joint angles measurement.
6. Conclusions
In this paper, the authors have shown the approach used in FCA based on simulation methods and experimental facilities to analyse ergonomics aspects of future workcells. The approach is based on virtual and physical methods that can be quickly used by project designers and plant ergonomics experts. Using these tools it becomes also possible to do a preliminary ergonomic analysis of the future workcell according to the most important ergonomics indexes (like OCRA and EAWS) in order to get a preliminary ergonomics optimization of workcells during the initial phases of a new product/process.

References