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A method for energetic comparison of 6-axis industrial robots and its further scope for resource-efficient plant design

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Abstract

Based on a systematic and comparable energetic assessment of 6-axis industrial robots, manufacturers as well as users of such robots gain various possibilities for increasing their resource efficiency.
The method described in this paper, which has been developed for this specific purpose, can nevertheless be transferred and extended to other complex assembly and manufacturing systems even with varying deployment scenarios. Thereby a cross-industrial benefit for optimal energetic operation of industrial manufacturing systems can be achieved.
By establishing centralized hosting and evaluation of all result data sheets, a large data pool could be created, which can be used for TCO-analysis as well as energetic and resource-efficient plant (*equipment*) design and, last but not least, for optimization of single components of manufacturing systems.

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Keywords: Assembly; robotics; energy efficiency; energy rating system; resource efficiency; body-in-white; automotive; plant design; TCO

1. Introduction

The reduction of energy consumption has been a major goal in a wide variety of research and development paradigms for years. Particularly in the automotive industry, with its strong focus on the product's energy efficiency, the primary energy required for its production becomes increasingly important. This phenomenon can be clearly demonstrated by the fact that the 3.5 MWh [1] energy required on average for a sedan's production is sufficient to drive up to 27,000 km distance with an advanced electric vehicle. [2] The overall process chain has to be considered to identify and

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ultimately realize energy savings potentials in vehicle production. Not only do the press and the paint shops emerge as particularly energy-intensive [3], but the car body shop is also identified as requiring large amounts of energy. The body shop's great energy demand mainly results from energy consumption by industrial robots, which is 8 MWh annually for only one 6-axis robot in this application scenario [4]. To achieve significant energy savings for industrial robots, it is necessary to compare the commercially available systems to determine and ultimately implement the most efficient robot in each case for a specific task. This comparison is also necessary to find the robots' different power-related parameters. To make available the parameters required for this purpose, the Fraunhofer IWU, in collaboration with the German car manufacturers' initiative for automation (German abbreviation AIDA), developed the "AIDA Energy Certificate for Industrial Robots in the Body Shop". [5] The related process instructions [6] include all the required boundary conditions, as well as the process steps to quantify and assess the energy consumed by the 6-axis industrial robots - from the definition of a reference trajectory and a reference load up to the determination of reference numbers (*characteristic indicators*) and charts, which are published in a standardized result data sheet. With the information in this data sheet, it is not only possible to compare different manufacturers and models in terms of the energy consumed and to estimate the real power input in the manufacturing process, but also to perform a TCO consideration (Total Cost of Ownership) whose lifecycle consumptions are considered in a validated analysis. Using this information, significant energy savings can be achieved when planning new body shop equipment, both by using particularly efficient robot models and through a load-appropriate design of the equipment's periphery. The methodology developed within the scope of this case of application can be transferred to other ranges of robot application outside the body shop, and entirely different production systems, such as gantry-type handling equipment or machine tools.

2. Energy certificate for robots

The following sections describe the induction of the parameters for the final assessment and the generation of the corresponding certificates. The robots are in general subdivided according to their nominal load-bearing capacity, ranging from 5 kg to 300 kg, in 50 kg increments.

2.1. Reference trajectory

A standardized and uniform test scenario is the basic precondition for the comparability of two systems. Considering robots, this is the trajectory motion of a specific operating point executed when fulfilling a predefined task. In general, the motion is traced using the tool center point (TCP).

The TCP represents a real or even virtual point of the tool mounted at the flange for the robot hand of the sixth robot axis. Archived data from robot programs designed for the body shop were subjected to statistical analysis in terms of characteristic parameters, such as point coordinates, movement types (*kinematic types*), trajectory lengths, velocities, approximation values and accelerations in order to define the specific reference trajectories for each load-bearing capacity class. The analysis results are described in detail in [5]. These data are subjected to subsequent mathematical cluster analysis, and probability distributions can be determined for all the trajectory parameters investigated. When calculating the reference trajectories, approach points are statistically determined and parameterized afterwards based on the probability distributions found.

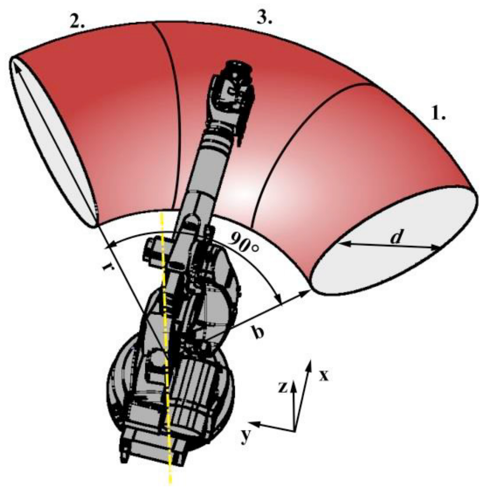

Figure 1: Trajectory segmentation (overview)