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Abstract: This article deals with the use of manufacturing process simulation as a verification tool. Simulation proves to be a valuable tool for testing and evaluating production processes and their effectiveness in a controlled virtual environment. The authors discuss the advantages that simulation brings, such as the identification of defects, the optimization of production parameters, and the prevention of problems even before the start of the real production process. The use of simulation of the production process enables the acquisition of valuable knowledge about the influence of various factors on the final product quality, the optimization of production procedures, and the minimization of the risk of errors. The authors emphasize that the simulation provides accurate information that helps in the decision-making process and allows the prediction of possible problems and their solutions before they arise.

1   Introduction

Simulation is a powerful tool used to address complex problems that cannot be effectively solved using simple mathematical models. The dynamic nature of these problems and the presence of uncertainties make simulation an appropriate approach. Different types of simulation can be categorized based on the specific problem they aim to support. For instance, managerial or strategic problems can benefit from simulation methods that are tailored to management-oriented scenarios, such as Monte Carlo simulation or scenario analysis. These methods can be further enhanced by incorporating visualization techniques or historical data. One practical application of simulation is in supply chain planning, which involves tasks like optimizing warehouse positioning or selecting suppliers. Simulation can provide valuable insights and aid in making informed decisions in such scenarios [1,2].

The other type of problem that simulation can address is technical in nature, specifically operational problems that arise in engineering. These problems require technical simulation methods to make informed decisions. They are often associated with the concept of the digital factory, which emphasizes the use of simulation in the engineering and manufacturing domains. This paper distinguishes between two types of technical simulation: simulation of

complete production processes and machine-oriented simulation focusing on individual manufacturing cells [3].

The primary objective of the first type, simulation of complete production processes, is to support the planning of specific production processes or improve existing processes by analyzing key performance indicators such as cycle times or Overall Equipment Effectiveness (OEE). The goal is to optimize these processes and identify areas for improvement. This type of simulation is crucial for enhancing efficiency and productivity in manufacturing operations (Figure 1).
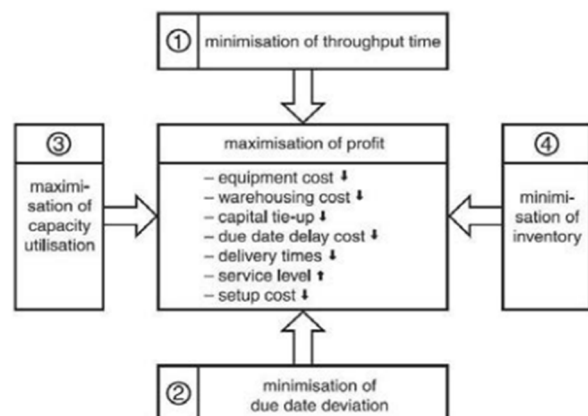

Figure 1 Goals of process simulation [3]

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Horizontal and vertical extension of simulation models in an enterprise

The traditional simulation tools have been effective in modeling various aspects of manufacturing, including manufacturing lines, flexible manufacturing systems, and manufacturing cells. However, the future development of simulation systems is focused on advancing integrated enterprise modeling in two main directions (Figure 2).

Firstly, there is a push toward integrating simulation models with broader enterprise-level systems. This means that simulation is not limited to individual components or processes, but rather aims to capture the entire enterprise and its interdependencies. This integrated approach enables a more comprehensive analysis of the enterprise as a whole and allows for better decision-making across different functional areas.

Secondly, the development of new simulation systems is also directed toward enhancing the capabilities of modeling complex interactions and dynamics within the enterprise. This includes considering factors such as supply chain networks, resource allocation, and information flows in a more interconnected and realistic manner. The goal is to create simulation models that can capture the intricacies of the entire enterprise system, enabling more accurate predictions and evaluations of its performance [4].
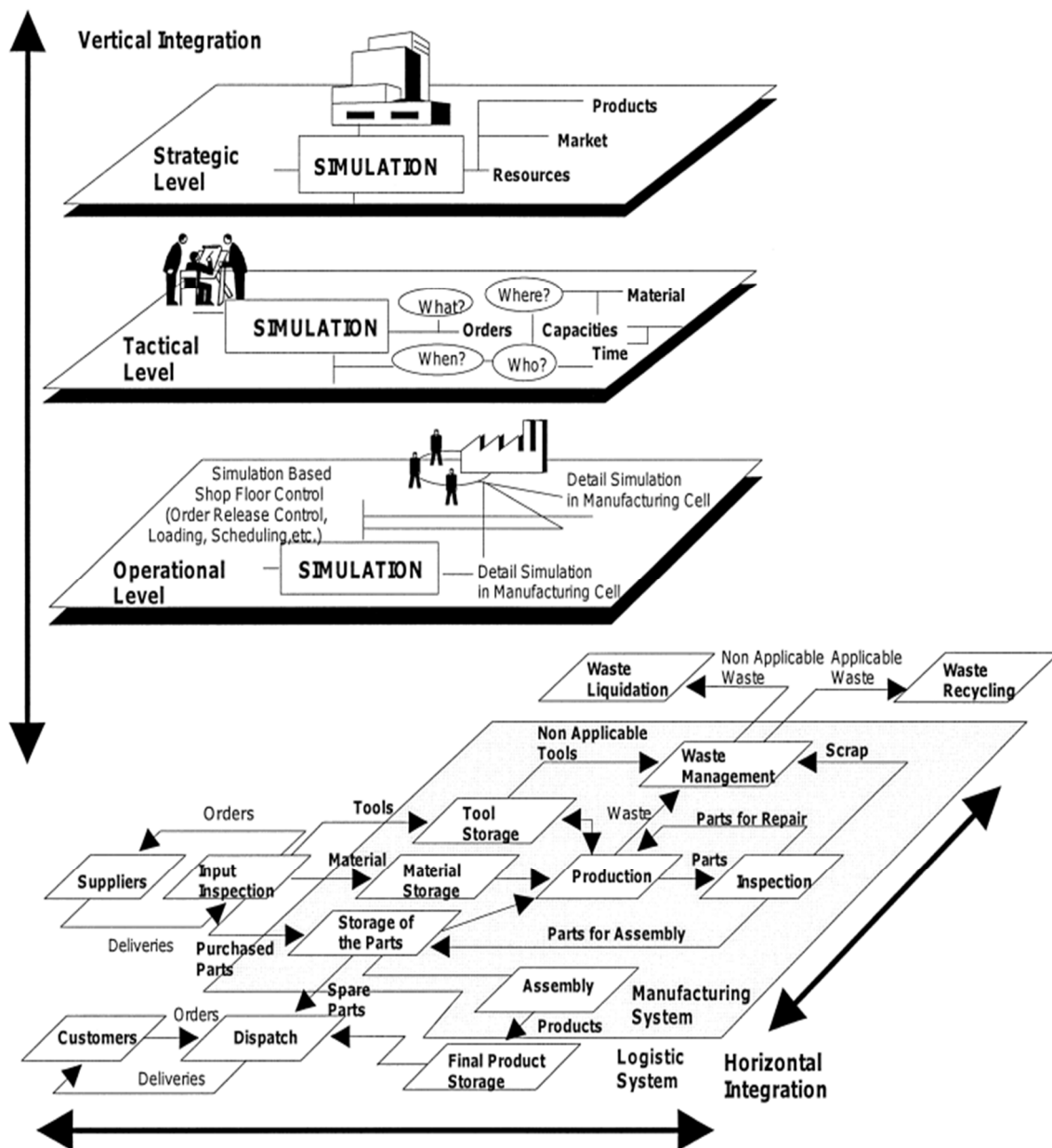

Figure 2 Integration of simulation modeling in enterprise [4]

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Horizontal integration involves the integration of manufacturing and assembly processes with the entire logistics chain of the enterprise, including external processes with suppliers and various supply strategies, distribution networks, market dynamics, demand forecasting, and other related factors. This integration aims to create a seamless flow of information, materials, and resources throughout the entire manufacturing environment.

On the other hand, vertical integration pertains to the integration of decision-making processes at strategic, tactical, and operational levels within the production planning and control system. At the strategic level, an aggregate system is modeled without including detailed operating or control logic. Strategic-level decisions involve long-term plans for production requirements and production resources. The objective is to align planned and actual requirements and resources to the greatest possible extent, ensuring effective utilization of resources and meeting production goals.

2 SolidWorks animation

SolidWorks is a professional software for 3D modeling, design, and technical documentation. Its many features include the ability to create animations. SolidWorks Animations allow users to create moving visualizations of their 3D models (Figure 3), allowing them to better understand the design and operation of the proposed product.

SolidWorks offers a variety of animation methods, including component animation, part animation, condensed assembly animation, and camera view animation. Users can define movements, rotations, transitions, and other parameters to create smooth animations. In addition, effects such as lighting, shading, and textures can be added to enhance the visual quality of animations.

SolidWorks Animations are useful for presenting and communicating designs with other people, as well as for verifying the functionality and movement of designed parts. They allow designers and engineers to visualize and analyze their projects before they are physically created, contributing to faster and more efficient product development [5].

SolidWorks Animations include:
- **Setting a Timeline**: When creating animations in SolidWorks, you can set a timeline that determines how movements and changes occur over time. You can define different animation stages and assign specific time intervals to them.
- **Keyframe animation**: SolidWorks Animations use a keyframe approach, which means that you define certain keypoints (keyframes) in time and the system automatically interpolates between

them. In this way, you can create smooth movements of objects or components.
- **Physical animations**: In addition to animating the components themselves, you can also use physical animations in SolidWorks. This means you can use physical properties like gravity, elasticity, friction, etc. to make objects behave according to the real laws of physics.
- **Camera and view animations**: SolidWorks Animations also allow for camera and view animations. This allows you to create dynamic tours of your models from different angles and perspectives.
- **Export animations**: After creating animations in SolidWorks, you can export them to various formats such as AVI, MP4, WMV, etc. You can then use these animations for presentations, websites, or other projects.
- **Interaction with other SolidWorks features**: You can easily integrate SolidWorks Animations with other features in SolidWorks. For example, you can create animations for collapsing or expanding components within a drawing or documentation. It is also possible to create animations for simulations within the SolidWorks Simulation module, which shows deformations and movements of materials.
- **Setting animation properties**: SolidWorks Animations provides various setting options that affect the visual output. You can adjust the animation speed, transitions between movements, control the duration of individual sections, and other parameters to achieve the desired effect.
- **Communication in assemblies**: Animations in SolidWorks allow you to display movement and interaction between different components in an assembly. This is very useful when examining the movement of individual parts and their proper functionality.
- **Motion and Collision Verification**: SolidWorks Animations can also be used to verify motion and detect collisions between components. In this way, you can detect potential problems in the proposed system before it is physically created.
- **Visualization settings**: SolidWorks offers various options for setting the visual page of animations. You can add different materials, colors, textures, and lighting for better visualization and a realistic look [6].

In the SolidWorks program, it is possible to animate various processes, be it production, kinematics, or motion. Figure 3 shows a robotic arm created in SolidWorks. As a classic 3D model, it is assembled as an assembly. In this mode, it is not possible to move it directly. It is necessary to set the degrees of freedom.

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Defined degrees of freedom:
- gripper movement,
- movement of the gripper head,
- short and long arm movement,
- tower movement.

If the degrees of freedom are defined, the model behaves as a moving part. Subsequently, you define the object to be moved from position A to position B. In this case, it is a cube, but if the requirements in production are different, any model can be uploaded. The last thing to do is to set the gripper, to its zero position, fix the cube and move to position B.

If these requirements are defined, it is possible to start the animation of the transfer process.
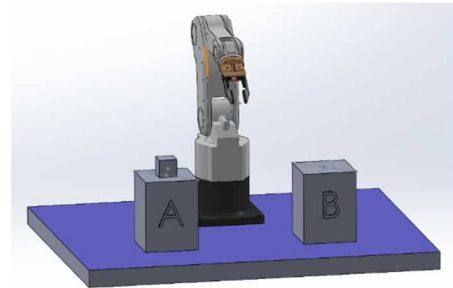

Figure 3 Setting up the robotic arm

Figure 4 shows the animation of moving the cube to the positions. In the Animation section of the SolidWorks program, it is possible to start and define animation properties. Using the displayed points of the animation of the individual parts, the exact time frame of the movement and the return to the initial position, the so-called zero point, is defined. Animation as part of the simulation helps companies define the equipment they use or will use safety features (exactly defined space where personnel can move and where it is already dangerous) as part of the renewal or optimization of the production process.
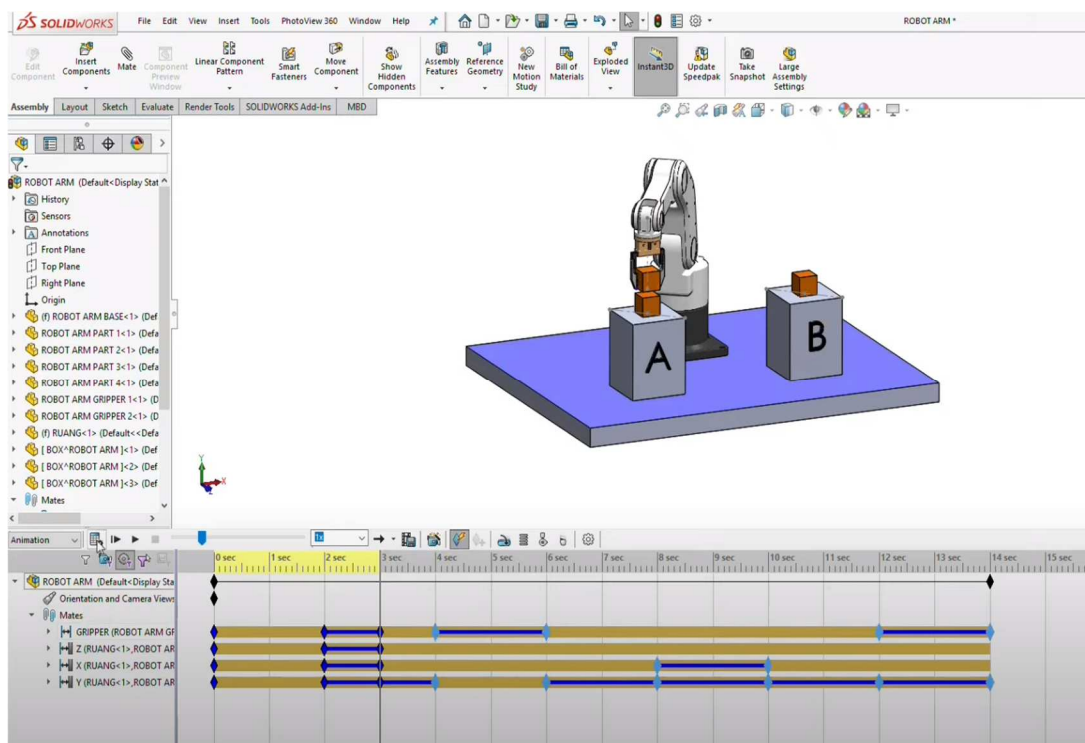

Figure 4 Animation of the work of the robotic arm

Another example of process animation is the production of plastic prints. Figure 5 shows part of a plastic press. A partial 3D model is sufficient for animation because only this part performs movement, the rest of the machine is static. The procedure is very similar to the robotic arm. Define the degrees of freedom of the part, connect them using the Mate tool of the program and check the functionality of the press assembly.

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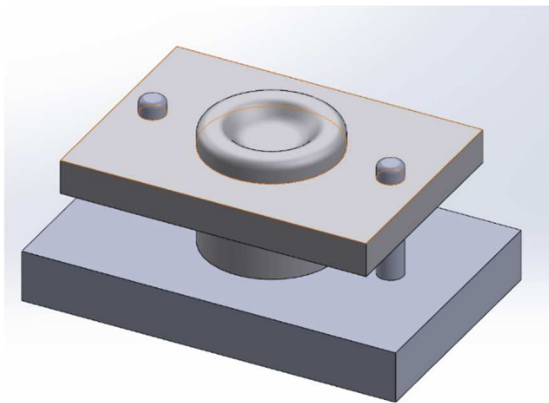Jan Kopec, Miriam Pekarcikova, Marek Mizerak, Jozef Trojan

Figure 5 A partial model of the press equipment

Creating an animation of a pressing device (Figure 6) in the SolidWorks program is possible using various techniques and functions. Here is a procedure that can help you create this type of animation:

- **Create a model of the press**: First, you need to create a 3D model of the press in SolidWorks. This includes the creation of individual components (eg arm, press plate, injection tool) and the assembly of these components.
- **Define motion patterns and dependencies**: Next, you need to define motion patterns and dependencies for individual parts of the pressing equipment. This includes determining the movement of the arm, the precise opening and closing of the press plate, and other parameters that affect the movement of the equipment.
- **Create animation using the keyframe approach**: You can use the keyframe approach in SolidWorks to create animation. Place keyframes in time for various parameters and positions of individual components. SolidWorks then interpolates between these key points, which creates a smooth movement of the device.
- **Set Timeline and Transitions**: Set the animation timeline and add transitions between key points. This allows you to define the speed and duration of individual parts of the animation and create smooth transitions between different movements.
- **Add visual effects and textures**: To enhance the visual quality of the animation, you can add various visual effects such as lighting, shading, and textures. These effects can enhance the details of the molding equipment and create a more realistic appearance.
- **Verify the animation**: After creating the animation, play it and verify that the movement and flow are in line with your expectations. If necessary, adjust the parameters or positions of the key points to achieve the desired result.
- **Export the animation**: When you are satisfied with the result, you can export the animation of the pressing device to the desired form. SolidWorks allows you to export animation to various formats such as AVI, MP4, WMV, etc. You can then use this exported file for presentations, websites, or other projects.
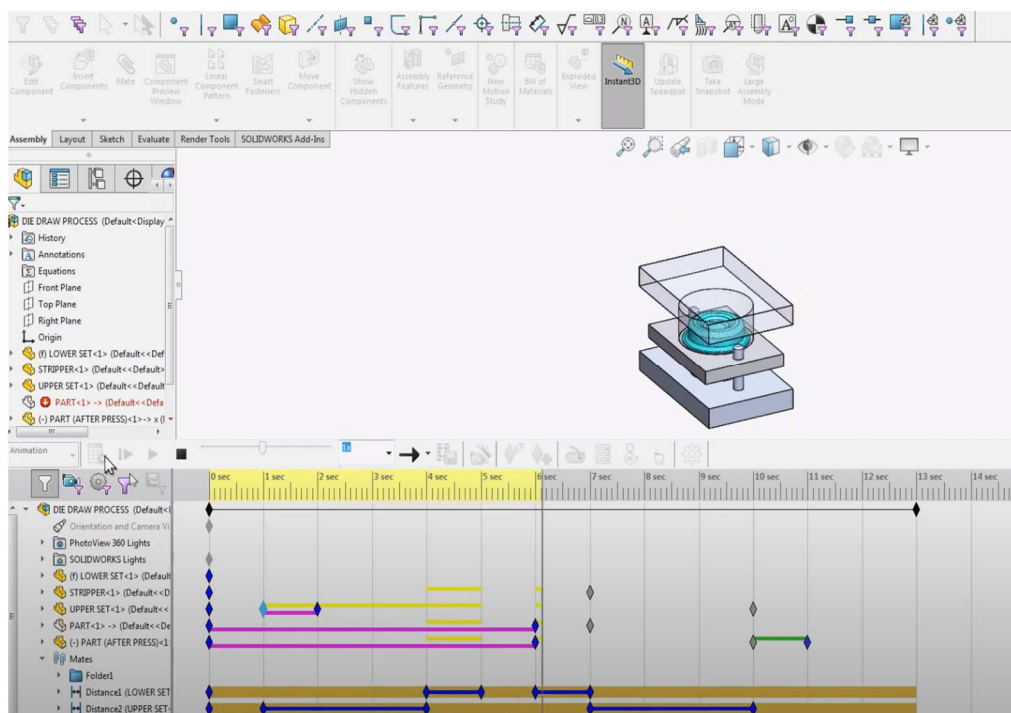

Figure 6 Animation of the pressing device

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In addition, in SolidWorks, it is also possible to create simulations of the pressing process, where you can model material deformations and monitor force effects during pressing. These simulations create a smooth transition between the initial and final state, which allows for more accurate visualization and analysis of the molding process

3   Conclusions

The use of production process simulation as a verification tool brings many advantages and perspectives to modern industry. This method enables accurate and thorough testing and evaluation of production processes and their effectiveness in a controlled virtual environment. The simulation enables the identification of potential defects, the optimization of production parameters, and the prevention of problems even before the actual start of the production process.

Verification using simulation enables obtaining valuable knowledge about the influence of various factors on the final product quality, optimizing production procedures, and minimizing the risk of errors. In this way, businesses can save time, resources, and costs that would otherwise be required to test and iterate real-world manufacturing processes.

Simulation tools enable the modeling and simulation of various scenarios and conditions, thereby enabling a holistic view of the production process. The results of these simulations provide reliable and accurate information that helps in the decision-making process and allows us to foresee possible problems and their solutions before they arise.

The use of production process simulation as a verification tool is therefore invaluable in modern industry. It provides companies with the opportunity to improve the efficiency, quality and competitiveness of their production processes. With the development of technology and the ever-increasing power of computers, production simulation is becoming more and more accurate and efficient, thus contributing to innovation and progress in the industrial sector.

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