# Simulation and analyze a production line by using Arena: A case study

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## Abstract

In many companies and manufacturing systems, Managers and engineers are looking for methods to find problems their production line like bottleneck so that they eliminate them whereas they want to obtain more productivity at the same time. Simulation is an appropriate tool to find and catch this purpose. In this project, a simulation computer is applied on a line production in a production line as a case study and by considering information obtained from simulation, bottleneck is determined, generating station and hand washing station. Then to increase productivity, two recommendation is proposed, both of them is investigated so that to find which bottleneck is more critical. Results shows that by increasing the machine in generating station and increasing labor in washing hand station, the company would be able to achieve higher utilization by 25% than the current system.

## 1. Introduction

Nowadays, manufacturing systems have become progressively complex and costly. In the one hand, manufacturing companies are trying to find useful methods to decrease the common problems in the production line such as bottlenecks and waiting times. On the other hand, companies are striving to sustain their competiveness by decreasing the bottlenecks, total cost and increasing the productivity. To achieve these goals, different methods can be applied to deal with different kinds of industrial problems which have effect on the manufacturing system productivity. Computer simulation is one of the useful methods have been used to evaluate of different manufacturing implementation scenarios in order to improve the productivity and decrease the bottlenecks. Moreover, using computer simulation in different fields such as manufacturing systems, construction projects, optimization of systems (Ebrahimi et al 2020) forming processes , Robatic (N. Ebrahimi et al. 2020) (Murat et al 2020) and electromagnetic systems (A. Jafari et la. 2020) (Ebrahimi et al 2020) and etc. have many advantageous such as saving money investment, increasing resource utilization, decreasing the process cycle time and enhance of throughput. There are many study conducted by researchers that by using simulation of a process like FEM process in forming (R. Rashidifar 2014), they can save money and time to get very significant and appropriate results Since the 1950s computer simulation has been used to tackle a range of business problems leading to improvements in efficiency reduced costs and increased profitability. Simulation studies have been carried out in most business sectors, including manufacturing and service industries as well as in the public sector. A simulation is a model that mimics reality; well-known examples are flight simulators and business games (Juhani 1999). There are many types of Simulation model can have several dimensions (Law et al. 1991):

- Static Simulation Models, time plays no role (particular time or steady state) Monte Carlo simulation
- Dynamic Simulation Models, model represents a system as it evolves over time
- Deterministic Simulation Models, no probabilistic (i.e. random) components
- Stochastic Simulation Models, at least one random input component
- Continuous Simulation Models, usually in process industry
- Discrete Simulation Models

Zahraee et al. (2014) applied computer simulation-based ARENA software to analyze and determine the bottleneck and then proposed to decrease the bottleneck and improve the productivity. An introduction section is required at the begging of your report. Some simulation studies conducted by Hutchinson (1991) in order to make easier decision to deal with production management problems. Mehmet (2013) discussed about using modeling and Taguchi analysis on flexible manufacturing system (FMS). Performance improvement of flexible manufacturing systems was evaluated by some simulation analysis (Tsai 2002). Computer simulation was applied to analyze the hard wood mill process as well as enhance productivity in wood industry by considering artificial intelligence methods (Dogan 1997, Basler et

al. 2002). Zahraee et al. (2014) presents the application of design of experiment and computer simulation to recognize as well as to weight the significance of different factors affecting the productivity of color industry production line.
In this project Arena software is an appropriate tool for simulation of a production line. The primary goal is to develop a simulation of whole production line in Arena software. It might help the company to find the many information about their processes especially where the bottleneck is and then as the final purpose, there would be some recommendation as "what if" scenarios that would improve production line.

## 2. System Description

### 2.1 Process Line

In this company production line divided to three general parts.

1- Surfacing that is including ART blocking, generating, engraving (laser), polishing, backside coating, ART de-blocking and surface quality check.
2- Anti-reflective (AR) coating includes AR washing, ultrasonic washing, sectoring, AR coating, de-sectoring, and AR inspection.
3- Finishing that is including tracers, edging, finishing, and final quality check.

The DC a section of the facility stores inventory of prescription lenses, frames, and contact lenses. When an order is placed, associates will go and grab the required glass blank, the required frames, based on the work order, and finally put them in a tray to send it off to the next station, ART Blocking. In this section the glass blank is glued to a block, providing more ease for the blank to transport and support all machining activities throughout the process. After the blank is glued, they are sent to the generation process. Here a machine creates a rough shape getting the lens closer to its final shape, size and curvature.
Once the rough shape is created the blank is sent to the laser engraving station where the work order number is engraved. After engraving, the lens will travel through the polishing station where the lens undergo multiple polish cycles. This is to smoothen the surface of the lens. Once the lens is done polishing, it will travel to the next station where the lens will undergo a scratch resistant back side coating. Following the coating station, the lens will go to the de-blockers, were the block will be separated from the lens. In Surface inspection, the quality of the lens is checked at this stage which includes power of the lens, polish quality, and coating quality. Next, the lens either goes to edging or will go to AR through a wash cycle to make sure the lenses are clean, and no glue from blocking is left on the lens. There are 3 variants in the AR recipes. After AR washing, the lenses are grouped into baskets based on the variant of AR coating. In sectoring section: To load the AR coating ovens, the lenses has to be mounted on to domes of same AR variant. Each dome can contain 120 lenses (60 jobs). AR coating: The domes with lenses are loaded in to the AR chamber and coated on both side of lenses. De-sectoring after AR coating, the lenses are removed from the domes and set in trays to send it to AR inspection. AR inspection checks the quality of AR coating and overall quality of the lenses. In figure 2, there are some tray including lenses and work order sheet that are waiting in queue.

Figure 2: Trays in line

Tracers will trace the shape and size of the frames. Edgers cuts the sides of the lens and shaped to fit their respective frame. After finishing where the lenses are popped into the frames, a final inspection is done on the glasses to assure they are manufactured as per customer request. Then the product is shipped off to the stores. In table 1, detail information about each stage and section has been shown

Table 1: Information of production line

| sections | Equipment | Current Machines | Hrly Rate | Equipment Uptime | Effective Hourly Output | Time taken for each job | Machine group Capacity |
|---|---|---|---|---|---|---|---|
| Surfacing | Blocking | 16 | 37 | 0.85 | 31.45 | 1.6216216 | 503.2 |
| | Generating | 6 | 30 | 0.85 | 25.5 | 2 | 153 |
| | | 6 | 35 | 0.85 | 29.75 | 1.7142857 | 178.5 |
| | Lasers | 13 | 150 | 0.85 | 127.5 | 0.4 | 1657.5 |
| | Polishers | 10 | 20 | 0.8 | 16 | 3 | 160 |
| | | 12 | 20 | 0.8 | 16 | 3 | 192 |
| | Backside Coaters | 12 | 62 | 0.85 | 52.7 | 0.96774193 | 632.4 |
| | De-Blockers | 8 | 65 | 0.85 | 55.25 | 0.92307692 | 442 |
| Anti-Reflective Coating | Wash Line | 2 | 189 | 0.85 | 160.65 | 0.31746031 | 321.3 |
| | AR Coaters | 9 | 38 | 0.85 | 32.3 | 1.57894736 | 290.7 |
| Finishing | Tracers | 9 | 50 | 0.95 | 47.5 | 1.2 | 427.5 |
| | Edgers | 8 | 36 | 0.85 | 30.6 | | 91.8 |
| | | 5 | 60 | 0.85 | 51 | 1.66666667 | 255 |

There are many ambiguous and problems that lead the company and its management to define a project about simulation of production line so that they would obtain a lot of information and analysis it in production line. The reason that the company mentioned is that they set up production line based on experiment. In other words, in the beginning, the company did not have the engineering approach and calculation. In result, there is no way to have an idea how well they perform and where the problems are. For instance, if they want to increase the capacity of production they have to know where is bottleneck in order to make a decision whether they need to increase worker or machines or even neither. It is obvious that simulation of production line as an appropriate tool help the company to find a standpoint and sight of whole their manufacturing system and the company would be able to find answers of its questions and problems. The simulation of production line helps the company to find bottleneck, waiting time in each station and many data related to their manufacturing system. According to all points and ideas mentioned above, in this project, production line has been simulated by Arena software.

Figure 3: production line

# 3. Current System Simulation

## 3.1 Arena Software

Arena simulation software enables manufacturing organizations to increase throughput, identify process bottlenecks, improve logistics and evaluate potential process changes. With Arena you can model and analyze process flow, packaging systems, job routing, inventory control, warehousing, distribution and staffing requirements. Successful plant operation requires that multiple process operations are coordinated to work at maximum efficiency. If your production line is unbalanced, the result can be increased WIP, higher off-grade material and a reduction in plant throughput. Logistics inefficiencies can also increase costs when production must stop due to resource constraints or available storage capacity. Simulation can help the companies to optimize their plant processes to reduce costs and improve throughput. There are many Features that encourage researchers to use Arena software including:

1. Easily Build a Manufacturing Process Flow,
2. Build a manufacturing process flow in a fast, intuitive and easy-to-learn manner.
3. Drag and drop elements and structures allow you build simulations and visualize results.
4. Engaging 2D and 3D animation capabilities that do not require programming assistance.
5. Built-in dynamic dashboards provide the model analysis you need to facilitate manufacturing optimization.
6. Build customized displays of the model information to enable you to better understand what is happening in your process.

## 3.2 production line simulation

One way to improve upon the manufacturing system was creating an Arena simulation of the current system. This simulation will give an overview of the manufacturing system and where the problem of the current system would be. By examining the simulation while running, the bottle neck of the system could be identified. The report of the simulation also showed detail which resource was lacking within the manufacturing system and which resource was redundancy. The simulation would also give an idea where to adjust to improve the throughput of the system.

Based on the data, the throughput of the manufacturing system within a day is around 5000 jobs, which also will be the goal of the simulation's throughput. The factory worked two shifts a day and each shift last 11 hours. Therefore, the simulation was set to run 22 hours per day. The simulation started from the point where the lens and the identify paper were assembled into the tray and ended after the final inspection ready for shipping. The first station is tray assembly. There are four workers at this station at a time. Each worker on average assembled 88 job per hour, which converted to 0.6818 minute per job and simulated as a Create unit in Arena showed below (figure 4).

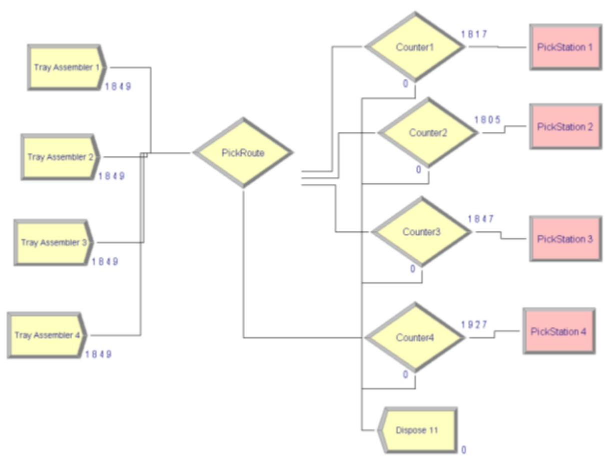


Figure 4: tray assembly station

The tray then transferred into one of the four different machining routes using Pickroute unit. The number of jobs should be equally divided between each route. There were five different type of machining processes within each route (Blocking, Generation, Laser, Polisher, and Deblocking). Machines were placed in series of each other. Each type of machining process had a specific number of machines. To simulate this, a Pickstation unit was created to decide which machine to go to if the other machine with the same process were busy. The first machining process was blocking. As represented in figure 5 below, Pickstation would choose one of the four Blocking station within Route 1 based on the queue line of Blocking 11. Each Blocking process was set with an average processing time with 85% equipment uptime in consideration. This Pickstation unit would simulate the actual manufacturing process where the route would decide which machine would be fed based on their availability.

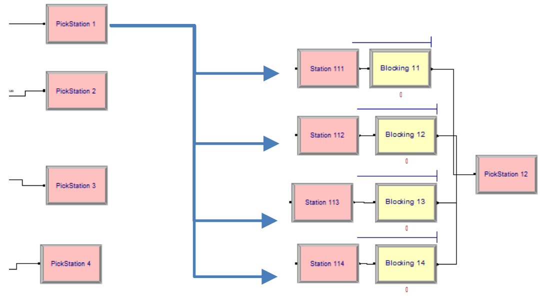


Figure 5: Pickstation station

Similarly, the other four machining process within each route were simulated based on the number of machine and their processing time. Same with other routes, noted that the number and type of machine can be different depend on each route meaning that all four routes are not complete same. Each route could have more machine in one type and the model can be different which effect their performance. In figure 6, the whole of production line is shown

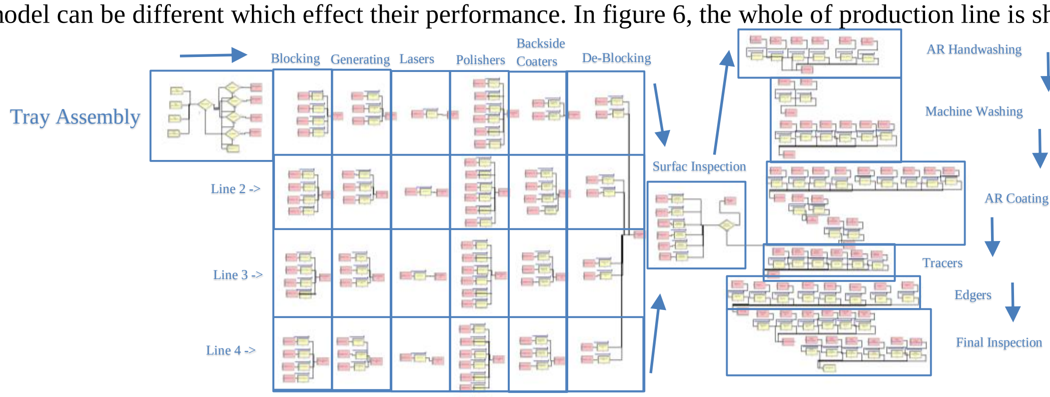


Figure 6: whole production line (current system simulation)

After De-blocking process, the job from four machining line would all come to Surface checking station is shown in figure 7.

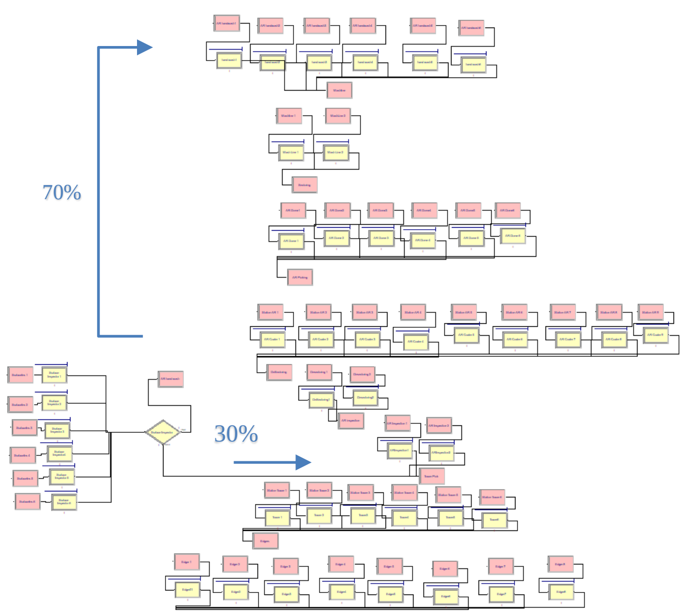


Figure 7: Surface checking Station

From this station, 30% of the job would skip straight to the Edger station. The 70% of the job would go to Washing station, sectoring, AR coating, de-sectoring, AR Surface inspection and then Edger and Final inspection. All process would be simulated similarly to previous process with a PickStation unit that would decide if one machine was busy, it would feed the job into the next available machine. Finally, all job will come to a Dispose unit name Throughput to show the number of job that the factory could manufactured in one run of the simulation.

**3.3 Result**

After running the simulation, the report showed that the number of entities input was 7748 and the number of output entities was 4057 which also was the throughput of the factory. It was lower than the expected outcome that was giving but within a reasonable in term of the different between real life and simulation. Therefore, the utilization of the factory was 52.4%. During running the simulation, a lot of the job within the system were holding back by the Generating machines and the AR hand washing station showing in figure 8. Therefore, the first problem that the factory had to deal with was Generating and AR hand washing process.

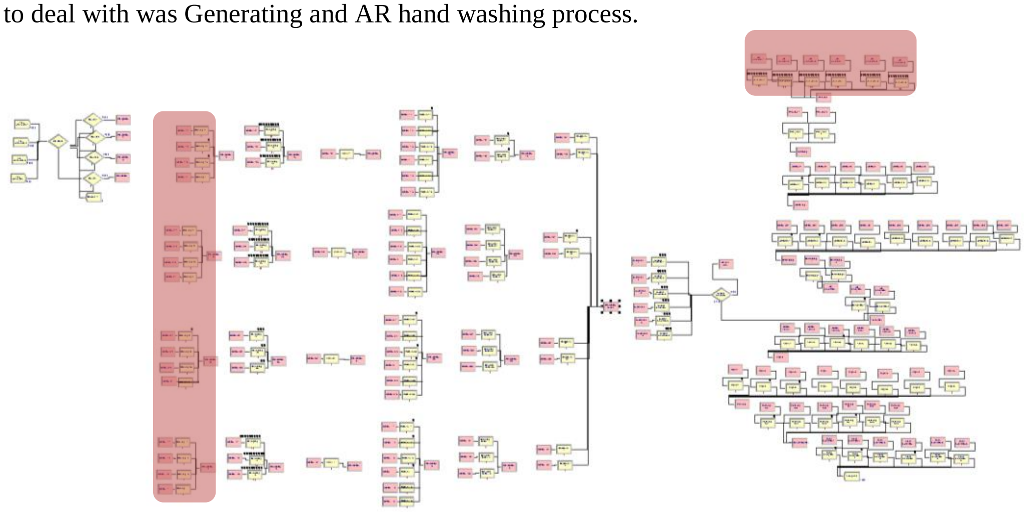

Figure 8: Generating and AR hand washing Station (bottlenecks are highlighted)

In figure 9, some results that are related to queue length in generating and AR hand washing process is shown.

| | |
|---|---|
| Finishing Up 2.Queue | 0.83 |
| Finishing Up 3.Queue | 0.71 |
| Finishing Up 4.Queue | 0.49 |
| Finishing Up 5.Queue | 0.22 |
| Finishing Up 6.Queue | 0.03 |
| Generating 11.Queue | 47.78 |
| Generating 12.Queue | 47.56 |
| Generating 13.Queue | 47.18 |
| Generating 21.Queue | 37.72 |
| Generating 22.Queue | 37.43 |
| Generating 23.Queue | 37.08 |
| Generating 31.Queue | 3.72 |
| Generating 32.Queue | 3.40 |
| Generating 33.Queue | 3.05 |
| Generating 41.Queue | 6.14 |
| Generating 42.Queue | 5.77 |
| Generating 43.Queue | 5.44 |

a- Queue length for Generating

**Other**

| | Number Waiting |
|---|---|
| hand wash1.Queue | 243.53 |
| hand wash2.Queue | 243.39 |
| hand wash3.Queue | 243.21 |
| hand wash4.Queue | 243.03 |
| hand wash5.Queue | 242.86 |
| hand wash6.Queue | 242.70 |
| Lazer 11.Queue | 0.10 |
| Lazer 21.Queue | 0.00 |
| Lazer 31.Queue | 0.20 |
| Lazer 41.Queue | 0.10 |
| Polisher 11.Queue | 0.51 |

b- Queue length for AR hand washing process

Figure 9: Queue length in generating and AR hand washing Station

## 4. "What if" simulation and analysis

Overall, based on the simulation result, since the bottle neck of the system had been identified as Generating and AR hand washing process, One way to solve this problem was to buy more Generating machines and AR hand washing workers in other to improve the throughput of the system. Two simulation was tested in order to figuring out which process (Generating and AR Hand-washing) was the actual bottleneck of the system. The first simulation was to increase of one Generating machine for each line (4 Generating machines). The increasing number of Generating yield

a small increasing in throughput. On the other hand, by increasing the number of AR Handwashing workers, the throughput of the system had increased significantly (more than 1000 jobs). Therefore, the biggest problem that the system had was the AR Hand-washing process which was the system's bottleneck. Further simulation was tested and final recommendation for the manufacturing system was increasing of 6 AR hand-washing workers, 1 more AR inspection station, 1 more Finishing up station, and 1 Final Inspection station.
The using the recommendation to update the simulation model had yielded an output of 5959 jobs. Comparing to the current system, the new model had reduced 1701 more jobs per day, which was a 25% increasing in the utilization of the whole system.

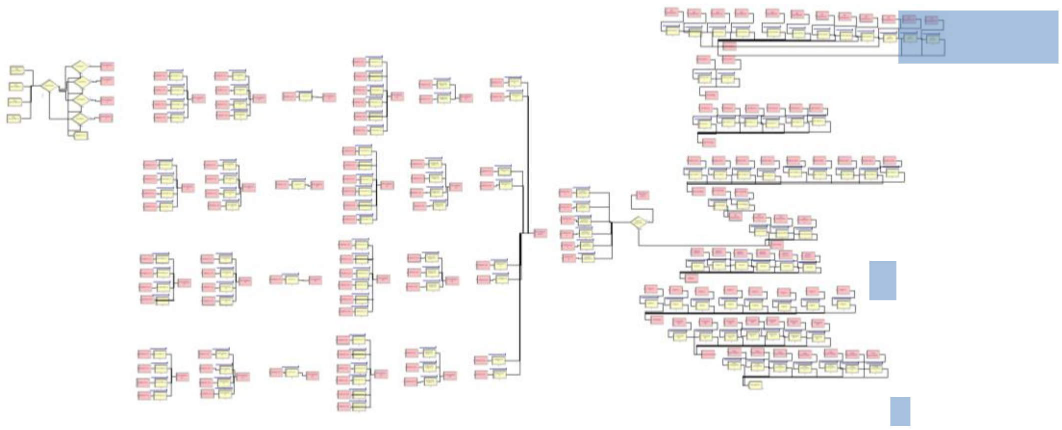

Figure 10: Updated Model simulation (Blue highlighted recommended change)

Table 2: compare between current model and proposed model

| | Current Model | proposed Model |
|---|---|---|
| Input | 7748 | 7748 |
| Throughput | 4057 | 5959 |
| Utilization | 52.3% | 76.9% |

There was room for improvement within the system like buying more machines and hiring more workers. However, since the cost of buying more machines was very high comparing to hiring more AR Hand-washing workers, and more AR Hand-washing workers yielded a significant increasing in throughput, it was not worth it to recommended buying more Generating machines.

## 5- Conclusion and Discussion

For decades the manufacturing industry has begun to show how their processes in factory can be beneficial. It is no longer about making a product as quickly as possible; it is all about making the highest quality parts and products for the customer. In manufacturing the goal is to always pursue perfection and in order to be successful there has to be a drive for continuous improvement, not just by upper management but by the workers as well. In this case study, it was shown that by using Arena simulation to create a current model of the manufacturing system, AR Hand-washing process had been determined as the bottleneck of manufacturing system. Based on the result of the current model simulation, changes were recommended to improve the system. A simulation of the recommended model had showed an increasing in 25% of utilization of the system. There was still some room for improvement within the system but the cost of it was not worth it.

## Reference

Basler, F., Moraga, M., & Ramis, F. (2002). Productivity improvement in wood industry using Simulation and artificial intelligence. Proceeding of the 2002 Winter Simulation Conference, (pp. 1095-1098). New Jersy.

Dogan, C., McClain, T., & Wicklund, S. (1997). Simulation modeling and analysis of hardwood Sawmill. Simulation Practice and Theory, 5(5), 387-403.

Ebrahimi, N., Bi, C., Cappelleri, D. J., Ciuti, G., Conn, A. T., Faivre, D., ... & Jafari, A. (2020). Magnetic Actuation Methods in Bio/Soft Robotics. Advanced Functional Materials, 2005137.

Ebrahimi, N., & Jafari, A. (2020). Energy and Force Optimization of a Network of Novel Electromagnetic Soft Actuators. Energies, 13(14), 3572. doi:10.3390/en13143572

Hutchinson, J., 1991, “Current and future issues concerning FMS scheduling”. Journal of Management Science, 19(6).

Jafari, Amir, and Nafiseh Ebrahimi. "Electromagnetic soft actuators." U.S. Patent Application No. 16/457,452.

Juhani Heilala, 1999, “Use of simulation in manufacturing and logistics systems planning”, VTT Manufacturing Technology, FIN-02044 VTT, Finland

Law, A.M., and Kelton W.D.,1991. Simulation Modeling and Analysis, 2nd ed. McGraw-Hill, New York

Mehmet Pınarbaşı & Çagrı Sel & Hacı Mehmet Alağaş , 2013, “Integrated definition modeling and Taguchi analysis of flexible manufacturing systems: aircraft industry application”, International Journal Advanced Manufacturing Technology (2013) 68:2169–2183.

Murat, R., Ebrahimi, N., & Jafari, A. (2020). Elastic Actuator Design Based on Bending of Cylindrical Beam for Robotic Applications. Actuators, 9(3), 80. MDPI AG. Retrieved from http://dx.doi.org/10.3390/act9030080

N. Ebrahimi, T. Guda, M. Alamaniotis, D. Miserlis, and A. Jafari, “Design Optimization of a Novel Networked Electromagnetic Soft Actuators System Based on Branch and Bound Algorithm,” IEEE Access, vol. 8, pp. 119324–119335, 2020, doi: 10.1109/ACCESS.2020.3005877.

Rashidifar, R., et al. "Comparison and Evaluation of Criteria Ductile Damage FLD & MSFLD to Predict Crack Growth in Forming Processes." the National Conference on Mechanical Engineering of Iran, Shiraz, Iran. 2014.

Tsai, C., 2002, Evaluation and optimization of integrated manufacturing system operations using Tagichi's experiment design in computer simulation. Computer and Industrial Engineering (43), 591-604.

Zahraee S. M., Golroudbary S. R., Hashemi A., J. Afshar, and M. Haghighi, 2014,“Simulation of Manufacturing Production Line Based on Arena,” Advanced Materials Research.

Zahraee Seyed Mojib , Shahab Shariatmadari, Hadi Badri Ahmadi, Saeed Hakimi, Ataollah Shahpanah, 2014, “Application of Design of Experiment and Computer Simulation to Improve the Color Industry Productivity: Case Study”, Jurnal Teknologi (Sciences & Engineering)