*Proceedings of the 10th International Conference on Manufacturing Research ICMR 2012, Volume I*
*September 11-13, 2012, Birmingham U.K.*

# MACHINE UTILISATION AND BREAKDOWN MODELLING FOR MEASURING PRODUCTIVITY USING VIRTUAL ENGINEERING SIMULATION MODELLING

Usman Ghani[1]
Radmehr P. Monfared
Robert Harrison

School of Mechanical and Manufacturing Engineering
Loughborough University
Loughborough
LE11 3TU, UK
[1]U.Ghani@lboro.ac.uk
R.P.Monfared@lboro.ac.uk, R.Harrison@lboro.ac.uk

## ABSTRACT

Results accuracy and reliability of discrete event simulation (DES) models to predict the production line productivities are based on the unexpected breakdowns taken place by machine faults or human errors. Process modeller practices DES modelling to incorporate these breakdowns and corresponding maintenances up-to the machine level. But actually breakdowns are potentially taken place at process level components inside the machine/stations. Domains like Virtual Engineering (VE) allow user to emulate the actual machine build from components using the CAD data and thus define the components level processes model exist inside the machine station. Therefore author came with idea to integrate VE and DES model up-to component level processes to get an improved simulation modelling to analyse the machines breakdowns for validating pre-build and after-build phases of machine development. Initially in this article it was proposed to produce an algorithm required to integrate and model the component–level DES model driven from the available emulated data models.

**Key words:** Virtual Engineering, Modelling, Productivity, Breakdowns

## 1 INTRODUCTION

Outputs of DES models to analyse machining and assembly operations can be used to estimate costs, productivities and proper labour requirements for existing and new programs. Therefore, simulation models required to reflect the real world as accurately as possible. In manufacturing systems, machine failure and corresponding maintenance durations are the important sources of variability. Therefore it should be presented correctly in simulation models up-to the desired process level granularity . These breakdowns, repairs and operator stoppages can have significant effects on the line yield. For example, the total loss due to these repairs and stoppages in an engine assembly line of for the three months was 18.7%[1]. Important to note is, that currently breakdowns modeller calculate the breakdowns up-to the machine level, but actually the breakdowns are taken place inside the machine because of faults in component. Therefore clear visibility is required to focus the breakdowns profile for machine components. Such level of breakdown granularity yield to focus the components and processes which are most susceptible to failures and thus easily diagnose the faults in case a stoppage take place. Another important aspect of these component level insight is to suggest the precautionary measures at the pre-build stages of machine/resources.

Virtual engineering (VE) are the emerging approaches partially used in industries to validate the initial design and geometrical interaction of the machine processes expected to be working on assembly line by using CAD data at pre-build stages. These emerging approaches helps to visualize and emulate the manufacturing environments to verify and validate the estimated and assumed data associated with machine processes (now a days only cycle times at machine level are verified). In component level analysis in virtual engineering, data could be managed at very early stage of the new or reconfigured process desired to be adopted. To take the advantage of this early available data particularly for the machine stations helps to replace the assumed and estimated data currently in practice by the process modeler with accurate and verified data.

Currently both of these domains VE and DES are in practice independently, but the usefulness of these domains could be enhanced if the component level process capability of VE application is extended for the productivity indictors available through generated results in DES. Therefore author proposed a novel technique to integrate the virtual engineering(VE) early available and validated data typically designed for components level breakdowns and repairs into the DES models to predict the impacts of these breakdowns on the production line outputs. This proposed integration and component level breakdowns and repairs modeling approach need other supporting modules such as proper data interacted information models required to captured the data when a modeling is done in the VE environment. Despite this also an integration suit flexible for user interfaces is required to be incorporated in the research process. All of the mentioned requirements need to shift the current DES methods and breakdowns modeling paradigms to components level pre build analysis. In this article author initially proposes the approach and algorithm needed to bring the proposal in practical existence.

## 2 CURRENT STATE OF ART

Extensive studies and researches have been carried out to model machine breakdowns duration in manufacturing system analysis. As a major source of randomness machine breakdowns have significant impacts on the manufacturing system production rates[2]. Typically state of art pointed towards two types of breakdowns one is deterministic such as shifts change, breaks and predictive maintenance, and random stoppages such as broken tool, operator error and machine failure[3]. Here focus is the random stoppages incorporation in productivity indicator projections.

Theoretically Binroth and Haboush believe that breakdowns are random and time dependent following the time pattern for future event according to the past event occurred[4]. But Bradford and Martin believes that breakdowns are not truly random but could be scheduled next failures in DES model with respect to previous stoppages[5]. It is also believed that breakdowns follow the bath-tub-curve as the life of machine passed away, which further complement the statement that mechanical failure are because of the physical wear, design errors, operator skills, electronics failures etc. over the machine life

Buzacott and Hanifin categorised that machine failures are occurred by two causes: (a) because of operation (b) because of time even the machine is idle still it is possible that machine may not work for example because of wear [6]. After knew about the random failure, important is to model these breakdowns as an input probability distribution functions into the simulation models. The common recommendation is that if a standard theoretical distribution can be found that is a good model for the input data, then this distribution should be used in the simulation model; otherwise, using the empirical distribution based on the data is a good option ( [2],[7]). As both the times to next failure and repair times are random and variant therefore they are term as mean time between breakdown and mean time to repair such as MTBF and MTTR respectively [8].

T.S. Bains and J.M. Kay produced the methods how to incorporate the DES techniques for modeling and productivity predictions when various production related variances are present in the analysis [9]. Number of DES tools such as Simul8, Arena and Witness simulation tools could server this purpose[2]. Despites of these factors and their impacts on the productivities, studies were carried out to standardize the process times for the machine. After reviewing the number of researches and studies it was concluded that for breakdowns and repair times modeling could be managed between two levels. One is to captured the breakdown and repair time durations. Second is to apply the statistical techniques to get the mean time for implementing in the DES analysis. Another main limitation identified from the state of art and industrial was the desire to bring the current breakdown modeling technique one level down to component level processes where actual failures occurs, and usually take longer time to prognosis and diagnosed the problem using current practices.

To overcome the current limitation, Virtual Engineering (VE) techniques can provide support to model the inside processes of machine at component level virtually. The virtual representation basically emulate the actual situation to visualize and validate the activities inside the machine stations. As part of this research number of possibilities were studied and author came with idea to model the component level processes inside the machine stations up-to very low level. And then verified and validated times pattern along with machine breakdown in form MTBF and MTTR. The validated data then could be translated in DES models to predict the productivity indicators in presence of probability function exist at components level. A number of commercially available virtual engineering applications can potentially facilitate control and monitoring of machine operations prior to the physical build. Examples of these applications include: Delmia by Dassault Systems[10], Process Simulate and UGX technomatix by Siemens[11], and Core Control Editor (CCE) by Loughborough University[12]. Most of VE tools can interpret systems' specifications in form of a standard data set, for example in form of XML format[13]. These script packaging depends upon the information required to interact the desired data inside the VE models. IDEF and UML [14] are the most common information modeling tools potentially used to capture data which are mandatory in simulation model through adopted VE channel. However, the natures of this data is often very different and a significant effort is required to interpret one to another. Currently, the authors are not aware of any attempt in industry or academia to have exploited such potential.

## 3 COMPONENT LEVEL APPROACH TO MODEL BRAKDOWNS

Typically component level process modeling is the beauty of adopted technology and approach. Using this approach it is easier to get insight behaviors of the process rather than relying on the machine level. Such a component level process analysis identifies the designated components which are most exposed to breakdowns and repairs. By doing so even at pre-build stage it would be easier to produce support for decision making process through guiding rules about how to deal the prognosis and diagnosis actions in case of breakdowns. It is needed to make it clear that component mean doesn't that the single small piece of the part used in the machine, but here in this approach component means that the combination of packaged parts which perform and contribute the single process inside the machine. Figure 1 is the representation of component based modeling of VE station. The illustrated figure is about the operation 01 indicated in part(a) also known as op01, which typically perform a nut tightening operation inside the collaborator assembly line. The designated process component for example at this station are:

- Motion of rail which take a pallet containing an engine, which need move towards station center.
- Lift processes which is combination of clamp process, and move to the nut tightening location, and then bring the engine back to home position and deliver it again on the pallet.

As an example the component rail process has been presented here in the mentioned figure, typically this process is the combination of different states incorporated in required process data such as when the rail start its motion towards the machine position it is the dynamic state which need speeds, when it stays on the machine position then it only takes time, then again it moves to the exit position, thus the associated process with this component behave like the actual situation present on the station op01 at the shop-

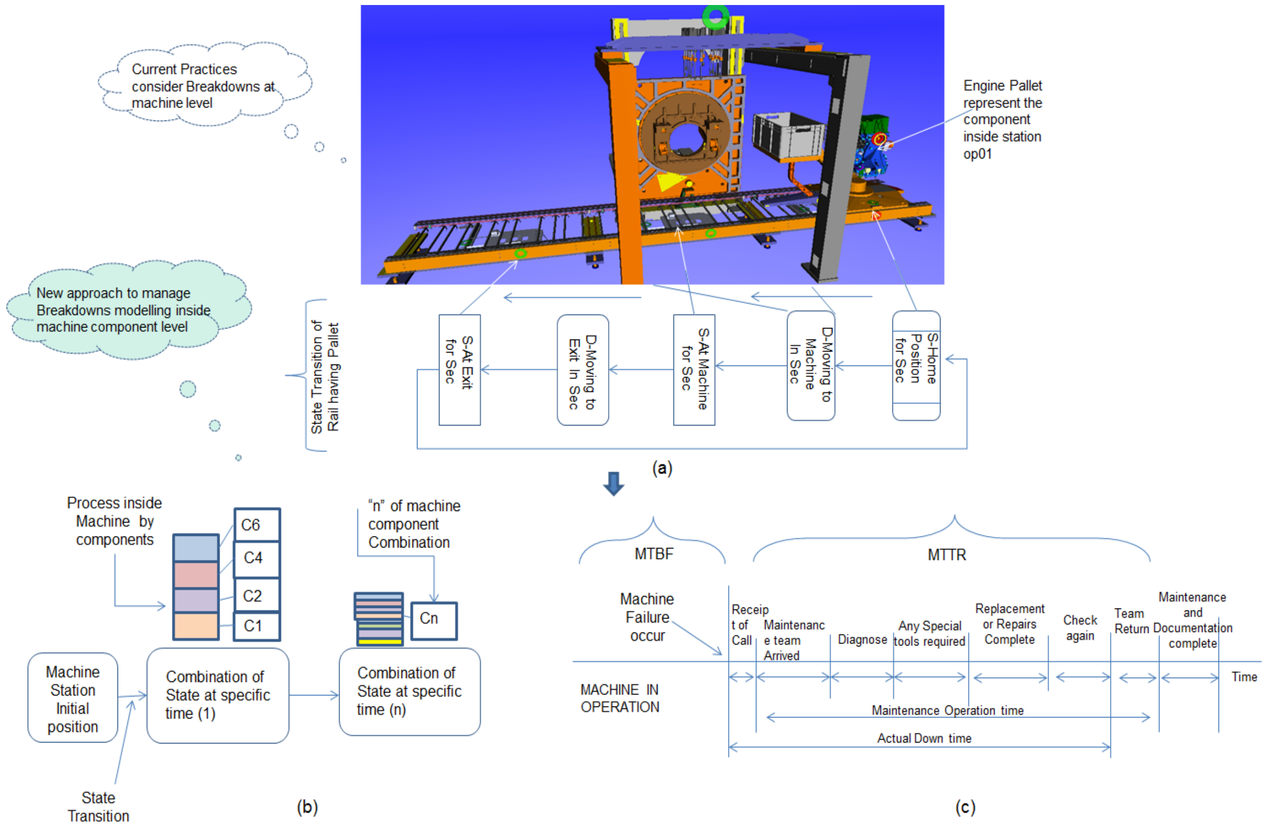


**Figure 1 (a) Example of Virtual Model of op01, and state transition of pallet and rail (b) Example of combination of components process (c) MTBF and MTTR model of breakdown and maintenance durations**

floor. In current practices for instance if this rail fails then the modeler consider the breakdown for the whole station, and thus the actual position and component which is responsible for this breakdown remains under-mind. Therefore the dark callout represent the novel approach of components breakdown and reliability analysis using the emerging VE simulation. The different component combination could be operated in parallel as well as sequential depending upon the requirement inside the station. As an example to address the concept working behind the component based reliability and breakdowns analysis approach Figure 1(b) represent the generic and conceptual visualization of the concerned components used inside the station at specific instant of time. While on the other side in part (c) of the figure model represent the event when a breakdown taken place. This model identify the variations which are possible inside the operations. For example first of all the MTBF is probabilistic by itself because it is not clear that at what instant of time the rail could be failed for example. Then the repair time has variations typically in, when repair team is called , when they do the repair, when they give ok signal for starting machine again. Therefore whenever to model the breakdown and repair variation inside the DES modeling important step is to know about the algorithm how to calculate the MTBF and MTTR, associated with the machine component for example the rail of op01.

## 3.1 Breakdowns modeling algorithm at component level

First of all it is required to have proper data capturing system for observing the stoppages take place at machine station and then to record duration, for which component was not working. This need a lot of historic data and span of time to keep the record for every component inside the machine. Once data is available then it is easier to be used it for existing machines and well as for the component which are used

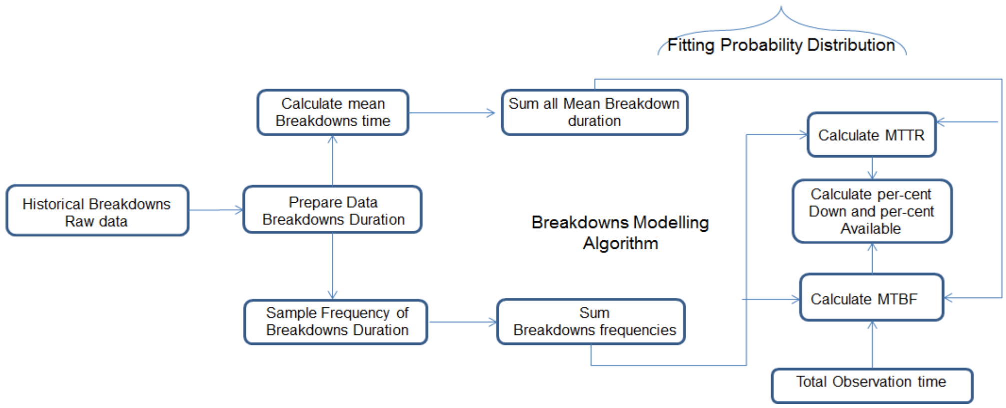


**Figure 2 Component Level Breakdowns and Maintenance patronising algorithm**

inside this machine or could be used in future machine. Figure 2 represent algorithm used to calculate the MTBF and MTTR for the components breakdowns. For example it is required to have the pool of historic data also known as raw-data, then get the breakdowns duration and their corresponding frequencies for getting total breakdown time. Onward it could help to get MTTR by using sum of the mean breakdown duration and frequencies as shown in algorithm. Which could further used in the DES modeling through the route of VE at prebuild stage of a process to predict the productivity indicator and viability of the process working inside the corresponding machine.

## 4 PROPOSED WORKING MODEL FOR VE DRIVEN DES MODELS HAVING MTBF AND MTTR

Figure 3 represent the working model of the approach suggested to predict the productivity indicator of manufacturing system when accounting the breakdowns at component level. VE is the main source of

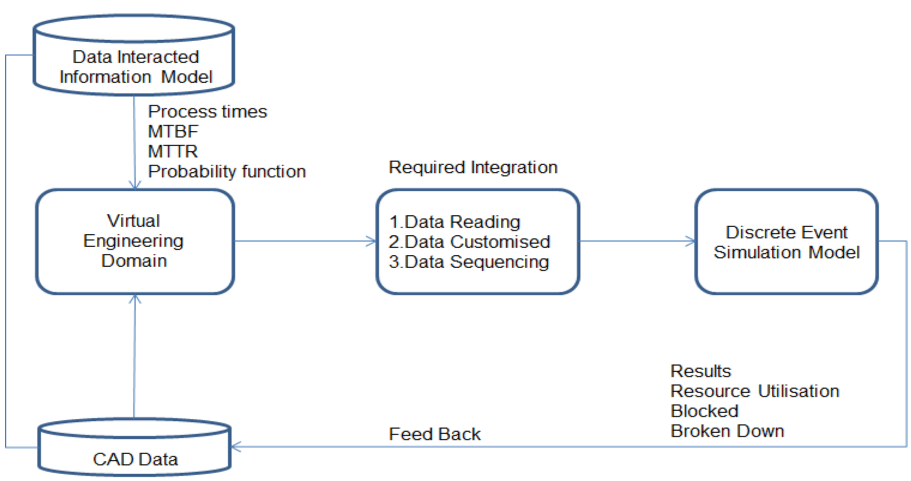


**Figure 3 Working Model of Component Level MTBF and MTTR including Productivity indicator using VE-DES integration**

support in materialization of this approach to facilitate pre-build and after build stages of machines with more accurate data translated in DES models. The integration between the VE and DES has already been developed by the author as part of this application development. Further the developed integrated platform is amended for reliability and breakdown analysis at machine component level. Mostly extension in this research is required to enrich the information model for interacted data inform of MTBF, MTTR along with their corresponding probability distribution at component level. Once the CAD component is dragged into the VE domain then the user would be able to add the required data being asked by the designated information. After the development and verification of VE model the validated data would be passed though the VDSim into the DES model and process modeler can observe the results in, for of the resource utilization, the component remain blocked and the time for which it remain broken down. Thus at pre-build stage a modeler can suggest the feedback for the design changes in model as well as in working procedures in form of feedback as shown.

## 5 CONCLUSION AND RESEARCH DIRECTIONS

Initially an approach was mentioned about the component level breakdown modeling at the pre-build stage of manufacturing system design. Then the algorithm and working model has been suggested, the corresponding models have been verified thought he domain experts. Further working model testing is required in case study.



## REFERENCES


[1] L. Lu, "Modelling Breakdown Durations in Simulation Models of Engine Assembly Lines," in *School of Mathematics*. vol. PhD: Southampton, 2009.

[2] M. A. Law, *Simulation Modelling and Analysis*, Fourth Edition ed.: McGraw Hill, 2007.

[3] J. Ladbrook, "Breakdowns Modelling- an Inquest." vol. Master in Philosophy: University of Birmingham, 1998.

[4] W. Binroth and R. K. Haboush, "Stochastic System Modelling Applied to an Industrial Production System," in *Internation Congress and Exposition* USA, 1978.

[5] T. C. Bradford and K. F. Martin, *International Journal of Modelling and Simulation,* 1993.

[6] J. A. Buzacott and L. E. Hanifin, "Model of Automatic Transfer: Line with Inventory Bansa Review and Comparison," *AIIE Transations,* vol. 10, pp. 197-207, 1978.

[7] S. Vincent, "Input Data Analysis," in *Handbook of Simulation* Newyork: John Wiley and Sons, 1998, pp. 55-91.

[8] M. Sondalini and H. Witt, "What is Equipment Reliability and How do You get It?," 2000.

[9] T. S. Baines, R. Asch, L. Hadfield, J. P. Mason, S. Fletcher, and J. M. Kay, "Towards a Theoretical Framework for Human Performance Modelling within Manufacturing Systems Design," *Simulation Modelling Practice and Theory,* vol. 13, pp. 486-504, 2005.

[10] W. Kuehn, "Digital Factory – Integration of Simulation Enhancing the Product and Production Process Towards Operative Control and Optimisation," *I.J. of Simulation,* vol. 7, pp. 27-39, 2009.

[11] A. Godwin, T. Eger, A. Salmoni, S. Grenier, and P. Dunn, "Postural Implications of Obtaining Line-of-Sight for Seated Operators of Underground Mining Load-haul-Dump Vehicles.," *Ergonomics,* vol. 50, pp. 192-207, 2007.

[12] I. Haq, "Collaborative Approach to Automation Systems Engineering for Automotive Powertrain Assembly," in *Wolfson School of Mech and Manufacturing Engineering*. vol. PhD Leicestershire UK: Loughborough, 2010.

[13] W. Kühn, "Digital Factory-Simulation Enhancing the Profuct and Production Engineering Processes," in *Winter Simulation Conference* Wuppertal, Germany, 2006.

[14] U. Ghani, R. Monfared, and R. Harrison, "Integrating Approach to Virtual Driven Generic Discrete Event Simulation for Manufacturing Systems," *Submttied to International Journal of Computer Integration Mnaufacturing (IJCIM),* 2012.