LOOKING FOR THE EQUILIBRIUM OF THE SHIELDS PRODUCTION SYSTEM VIA SIMULATION MODEL

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ABSTRACT

The use of simulation increasingly becomes part of business planning and analysis. Using a computer program a model that faithfully mimics reality can be easily created and used to analyze the situation in the company. In this paper simulation is used to accurately determine utilization of shields manufacturing machines and also to analyze the entire production process, which begins with the arrival of the material and ends with finished product. The first task is to search for the optimal utilization of machines, number of shifts and employees. Based on the results of the analysis number of produced shields and production process could be modified. The aim is to determine the current state of utilization and to find the equilibrium or ceiling for possible future expansion of production. SIMUL8 has been used as a model background. The results obtained from the simulation model have given new information and invaluable knowledge of the process to the company.

Keywords: shields production, simulation model, discrete event simulation, SIMUL8

1. INTRODUCTION

Simulation methods belong to the suitable instruments that can be used in the real world situations to better understand the reality or to make a responsible decision. Simulation means a technique for imitation of some real situations, processes or activities that already exist in reality or that are in preparation – just to create a computer model (Banks 1998). Models can be created in variant software depending on the type of the model. Sometimes Monte Carlo simulation for iterative evaluation of a deterministic model is sufficient but real simulation is usually made via discrete event simulation model or continuous simulation.

When we talk about the production process model it is usual using discrete event simulation to model the process. It means to describe all activities that are necessary during the production process, their duration, resources needed and their sequence. Discrete event simulation is very useful when studying the behavior of the system or looking for the bottlenecks of the system. As production belongs to the areas where it is hard to find the problematic processes that limits the whole system, discrete-event simulation serves there as a good tool. O'Kane et al (2000) showed how discrete event simulation (and model in WITNESS software) can help with the decision how the output can be increased. The automotive industry is typical for simulation usage – for example Masood (2006) tried to find how to reduce the cycle times and increase the machine utilization in an automotive plant. Montevechi et al (2007) shows that simulation is also good for the creation and testing of different experiments or scenarios.

2. MATERIAL AND METHODS

Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Key issues in simulation represent data acquisition of valid source of information, selection of key characteristics and behaviors, use of simplifying approximations and assumptions within the simulation, and also detection of fidelity and validity of the simulation outcomes (Law 2000). On the other hand simulation model can be created only thanks to the computer and simulation software. In this article we describe the simulation model of the shields production system created in the SIMUL8 software. Several case studies with similar approach to problem solving were published (O'Kane et al 2000, Aguirre, Mendéz 2005, Masood 2006, Montevechi et al 2007).

2.1. SIMUL8

SIMUL8 is a software package designed for Discrete Event Simulation (www.simul8.com).

Figure 1: SIMUL8 logo (www.simul8.com)

It allows user to create a visual model of the system under investigation by drawing objects directly on the screen of his computer. This software uses four main objects:

- Work Entry Points
- Storage Bin (or Queue)
- Work Center
- Work Exit Point

The characteristics of the objects are defined in terms of capacity, speed, etc. All these objects are link together by connectors that define the sequence of the activities and also the direction of movement of entities. Entities are other objects of the model. These dynamic objects (customers, products, documents) move through the processes and use various resources. Resources serve for modeling of limited capacities of the workers, material or means of production that are used during the activities.

Once the system is modeled a simulation can be undertaken. The flow of work items around the system is shown by animation on the screen, and for that reason the appropriateness of the model can be easily assessed. When the structure of the model has been confirmed, a number of trials can be run under different conditions and the performance of the system can be described statistically. Statistics of interest may be average waiting times or utilization of Work Centers or Resources (Shalliker and Rickets 2002).

SIMUL8 can be used for various kinds of simulation models (Concannon et al. 2007). The cases studies can be seen also on the web pages www.simul8.com or www.simul8.cz (in Czech Republic).

2.2. THE SHIELDS PRODUCTION PROCESS

Every production system consists of a lot of processes and activities that are sometimes hard to analyze by usual mathematical or analytical methods. Simulation is a suitable tool to do so. Our task is to create a model of the shields production so as to correspond with reality and afterwards analyze the effect of higher demand for these components. The main aim is to find the equilibrium for the company to meet the demand on the one hand and increase the number of machines minimally on the other hand.

The shields are produced in a Czech machine work company ZLKL as parts of electromotor alternators (Figure 2). Production of each shield is quite difficult process thanks to the requirements of accuracy.

Figure 2: Example of the shield for alternator usage (www.vltava2000.cz)

Before the raw material becomes a shield it must go through the whole production cycle. Raw material is transported towards the machine tools. After first treatment it follows to the procedures of turning, drilling, screwing and deburring. Then the shields must be degreased. Before packing they are randomly controlled if they are of the given size. The entire production process, as well as the expected form of the simulation model is shown in Figure 3

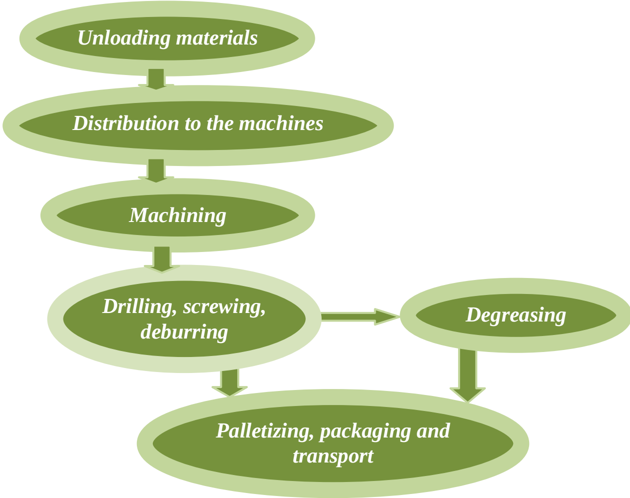

Figure 3: The conceptual model

Table 1: Real average monthly production and expected production after increase

Shield Type	Avg. Monthly production	plan for a year	plan for a month	fulfillment of a plan
21297015025D_B	1585	35 200	2 933	54,00%
21297002001D_C	1061	25 800	2 150	49,30%
21297064001D	1243	35 200	2 933	42,40%
21297009001D_C	1298	33 000	2 750	47,20%
51298132101001_B	1524	26 400	2 200	69,30%
51298160101001_A	415	13 200	1 100	37,70%
21297007040D_B	0	35 200	2 933	0,00%
21297084001D_A	0	33 000	2 750	0,00%
21297064001D	0	35 200	2 933	0,00%
32417311673200	0	30 800	2 567	0,00%

production in pieces

Before the creation of the model we have to know something about the production and the production times. Table 1 shows the average monthly production of shields and expected (planed) production after the increase of the demand. We can see that only for one type for the shield the company is able to satisfy more than 50% of the monthly average demand. Some shields are not produced now. The average yearly production is more than 85000 different pieces but the new demand asks for production at about 417000 of different shields so nearly 5 times more. For the simulation model we have to know the times for material distribution, machining, drilling, screwing, deburring, palletizing and packing. The machine times have been known before (Table 2) but the times where human power is necessary we have to measure and try to find the best distribution for material transportation (Figure 4), palletizing and packing.

Table 2: Times in minutes per different operations

Shield Type	Turning machine	Time for turning (min/piece)	Drilling machine	Time for drilling, screwing, deburring (min/piece)	Degreasing (min/1 piece in batch)
21297015025D_B	EMAG	2,1	V20/4	3,33	0,004
21297000001D_C	SPR 100	11	V20/4	1,5	0,23
21297064001D	EMAG	3	V20/4	3,33	0,004
21297009001D_C	SPR 100	8,2	V20/4	1,5	0,23
51298132101001 _B	SPR 100	11	OC Lilian	1,5	0,23
51298160101001 _A	SPR 100	10, 5	OC Lilian	4,5	0,64

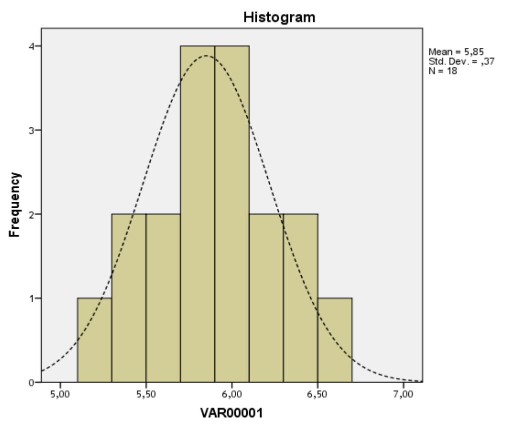

Figure 4: Time for material transport – distribution estimation

Simulation model uses those machine times known in advanced and corrected by the average scrap and delays caused by machine failures. The probability distribution has been set according to our own observations of the processes (normal distribution).

For the production it is necessary to comply with the number of shields of different types. The inputs of the basic model result from the updated information and material is split among the machines according to the percentage of the given type in the order. The model has been created so as each type of the shield would be shaped on different machine. The machine time for each shield is unique and this part is fundamental for the production process. Therefore it was necessary to create more machines within the simulation model than really exist and afterwards we had to summarize the capacity usage of these model machines. Before the summarization it was possible to see the workers utilization

3. RESULTS

According to the given conditions and know characteristics of the production process the first version of the model has been created (Figure 5).

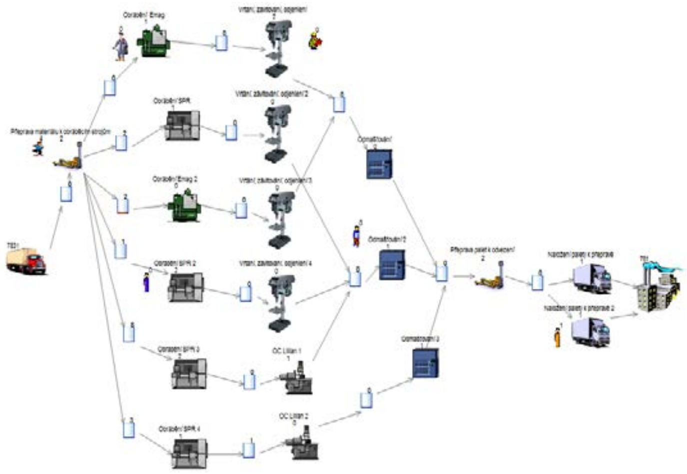

Figure 5: Simulation model of the current production

The results of the model agree with the real number of shields produces (Figure 6) and we can also see that the utilization of the machines is low except of one machine where the utilization is higher than 50% (but still it is not a problem). First one month and one shift simulation has been created and afterwards the results from the half-year simulation has been taken to validate the model (the warm-up time is included). The model imitates the real production and so it is good to use for the next analysis to find out whether the company is able to meet higher demand.

The next task is to check out the increase of the production. Today's shields production makes only 30% of the plan future expansion so production should be increased significantly. Whereas the first model supposed only one shift production in case of higher demand machines have to run for three shifts. The next model should show if it is necessary to use another machines and how and where to use it so as to be maximally efficient. The production expansion relates not only with the existing shields but also 4 new shield types should be produces, so instead of 6 types the company should produce 10.

The new model differs in number of EMAG machines – one machine should be used to produce three types of the shields. Also number of degreasers is four instead of three but both machines can be operated by one worker.

Except the added machines also other parameters have had to be changed such as the inter-arrival times of the material and percentage split among the shaped machines. Because of the different machine times of the drilling, screwing, deburring and degreasing some shields are processed on the same machines and so its routings in the simulation model merge and split up. Also material is split up according to the size of the shield types. The last change of the model has been the extension of the simulation time and warm-up period as instead of one shift production three shifts are used. The new model is on the Figure 7.

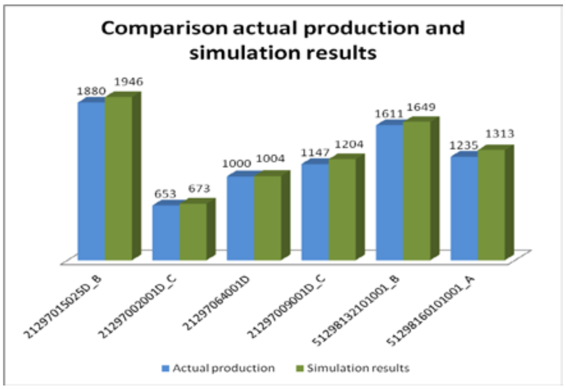

Figure 6: Comparison actual production and simulation results

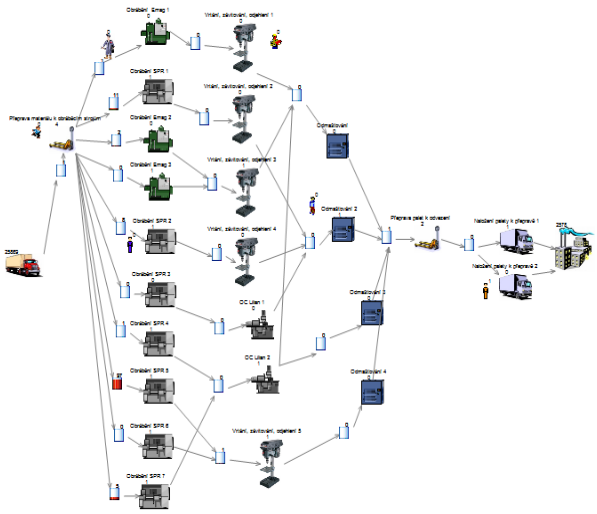

Figure 7: Extended simulation model

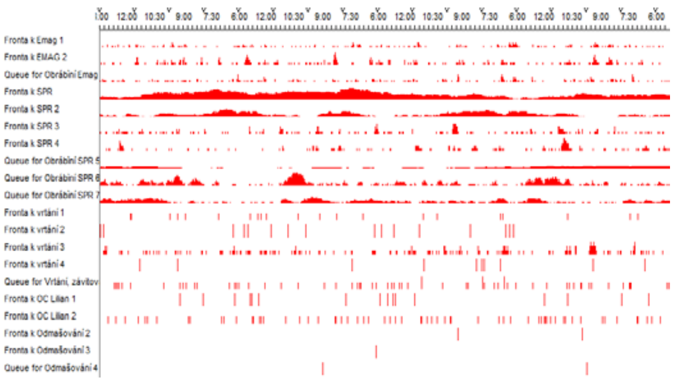

Figure 8: The queue size at a particular machine

Figure 8 shows the length of the queues in the production process after the production expansion. We can see that there are no serious problems except of the shaped machine SPR (the number of shields in a queue are described by connected red field). For the continuous production the maximum queue size is important as it is hard to store goods in process and it can stay in a way and complicate the movement in the hall.

Table 3 shows the length of the queues and the queuing time for each work center. We can see again that there are only two problematic places – shaped machines SPR 1 and SPR 5.

Table 3: Maximal and average queue size and time

Queue to Work Center	Average queue size (pcs)	Maximal queue size (pcs)	Average queue time (mins)	Maximal queue time (mins)
Transport Material	0,6	6,67	0,65	6,59
EMAG 1	0,32	6,17	3,03	130,61
EMAG 2	0,3	6,17	3,32	121,89
EMAG 3	0,36	6,83	3,39	41,26
SPR 1	11,65	33	116,65	8540,95
SPR 2	6,93	31,67	70,33	303,74
SPR 3	0,38	6,17	4,79	41,44
SPR 4	0,32	5,67	8,1	68,49
SPR 5	29,22	67,83	291,14	693,18
SPR 6	1,29	10	11,97	66,92
SPR 7	3,38	22	35,74	223,06
Drilling 1	0,03	1,83	0,28	2,85
Drilling 2	0,02	1	0,31	3,14
Drilling 3	0,29	4,17	1,36	13,83
Drilling 4	0,03	1	0,29	3,17
Drilling 5	0,08	3	0,39	4,65
OC Lilian 1	0,02	2	0,28	4,14
OC Lilian 2	0,11	2	0,78	7,58
Degreasing 1	0,01	2	0,02	0,81
Degreasing 2	0	2	0,01	0,78
Degreasing 3	0	1	0,01	0,27
Degreasing 4	0	1	0,01	0,64
Loading pallets to drop-off	0	2,33	0	2,42

Figure 9: Utilization of shaping machine EMAG

It is important to check the utility of each work center and worker. Usually we can display the graph of results to see the utility of the machine but as it has been mentioned above model contains more work centers than number of real machines so we have to summarize utilities of more work centers. It can happen that that the total utility is higher than 100% and the simulation model should be changed. Figure 9 shows the time when the shaping center is working and when is awaiting for material. Although it may seems the machine works only a small part of the shift, the total utility is 80%.

We have checked also the utility of the next work centers, the results are in Table 4.

Table 4: Cumulative utilization of work centers

Work Center	Utilization
Working EMAG 1, 2 a 3	80,00%
OC Lilian	71,49%
Degreasing	13,72%
Drill	75,82%

Except for the degreasing machine the utility of machines is quite high. Similarly the utilization of workers is shown in Table 5.

Table 5: Utilization of employees

Work position	Worker utilization
Transportion worker	95,53%
Drilling operator	75,82%
SPR operator	96,91%
EMAG operator	80,00%
Degreasing operator	13,72%

The utility for the EMAG operator is the same as the utility of the EMAG machine itself – it is because both machines are operated by one worker on each shift.

We have made sure of the fact that the total utility is not higher than 100%. Now we have to verify that the condition of the number of shields made has been met.

As in the first model this simulation model perfectly imitates target values (Figure 9).

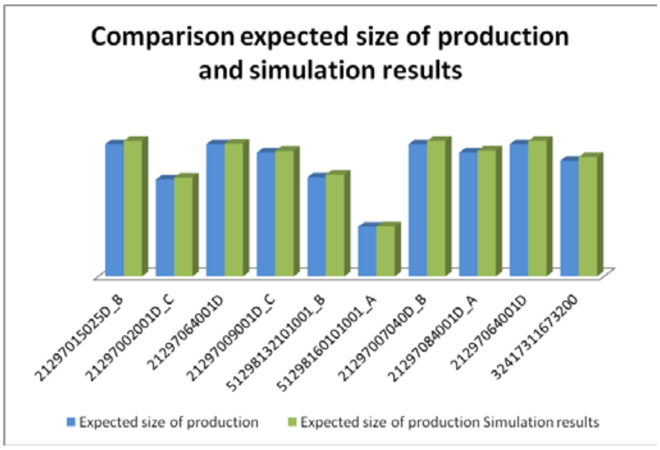

Figure 10: Comparison expected size of production and simulation results

Table 6 shows the expected production size and the results obtain from the simulation. It is clear that the all customers' requirements will be satisfied without problems also in case of higher waste.

Table 6: Comparing expected values and simulation results

Type of shield	Expected size of production	Simulation results
21297015025D_B	2 933	3 008
21297002001D_C	2 150	2 195
21297064001D	2 933	2 949
21297009001D_C	2 750	2 786
51298132101001_B	2 200	2 257
5129816010101001_A	1 100	1 108
21297007040D_B	2 933	3 007
21297084001D_A	2 750	2 791
21297064001D	2 933	3 006
32417311673200	2 567	2 652

All the changes of the number of machines have been discussed with the management of the company and with the workers that use these machines so as not to cause any problems in future changes. We have tested also different number of machines and try to find the minimal number for the demand satisfaction but with acceptable machine utility. The best results (as we can see as an equilibrium) has been described here.

4. RECOMMENDATIONS

All simulation results show us that the company is able to satisfy the higher order (that has been derived from the new contract offered). In all production system there should not be longer queues and we expect that also the waiting times for the cutting, drilling, degreasing or other production activities will be small and acceptable. On the base of the simulation model the production process has been analyzed in detail and we have discovered some placed where the number of machines or workers can be decreased or somehow change the production to be more efficient.

The shaping and cutting center EMAG which is utilized on 80 % (Table 5) can produce three types of shifts numbering about 8964 pieces. This machine is very quick and precise compared to the other shaping machines SPR and its spoilage is nearly zero. If we compare the production of nine SPR machines for the same time we can see that they are able to made 16 795 pieces on average with similar utility. Average shaping time on EMAG is about 2,5 minute whereas on SPR machine is nearly 4 times higher. In case of buying new EMAG VL 7 center the time savings are very high. The next advantage can be the fact that only one worker can operate this new machine during each shift and so it can generate more money savings for the company. On the other hand the price of the machine is very high but could be decrease via selling the old and redundant SPR machines. This change could save the space in the hall and this is also very important as there is never enough space.

Thanks to the possibility of the graphical representation of the machines utility it is clear how much of the labor time the machines are working and how much time they are waiting for the next product. In the simulation model seven work centers for cutting, deburring and shaping are modeled. Two of them are the shaping centers Lilian where the utility is pretty good. The next five centers are drilling machines (in reality they are only three but according of the conditions of production it was necessary to model it by five centers). We can see on the Figure 11 their utility and the total sum is equal to 156%. It means that it is possible to use only two drilling machines instead of three and use the remaining machine for the different order.

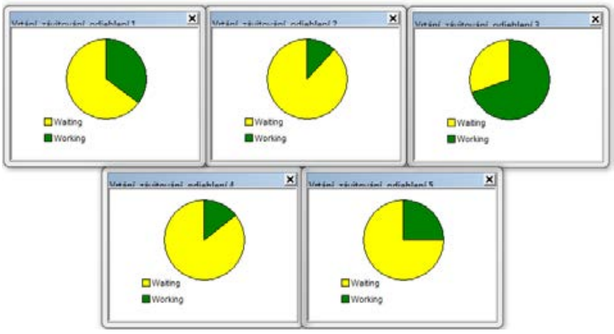

Figure 11: Utilization of drills

Degreasing is the last place where we can reduce production from three shifts to one. Because of the big batch degreasing at a time the utility of this workplace is very low (Table 4), only 14%. That is why the degreaser can work every third shift. Shields storing for a period of two shifts is acceptable for the company and the shields will not complicate the movement in the production hall. Some containers or palettes can be used nearby the degreaser to store the products. Moreover the degreaser can be used for another production and that is why it is possible to decrease the number of shifts (especially during the night because of extra charges that can lower the cost) of the following operations as pallet packaging and transport of the final products.

All parts and changes of the model has been discussed with the management of the company and we have also communicated with workers when measuring the working times. The changes meet the requirements of the new client and its new order (the higher production) but also it meets the requirements of the company (change the machines and number of machines so as to increase the utilization but acceptable for workers). From this point of view the equilibrium has been found.

5. CONCLUSIONS

The aim of this article is to find the equilibrium for the shields production system to produce ordered pieces with optimal number of machines. First we describe the creation of simulation model of the shield production process made in the software SIMUL8. The model corresponds with reality and so it has been possible to do some changes especially analyze the effects of higher demand. According to the simulation results some recommendations for the company relating workers and machines has been made.

REFERENCES

Aguirre, A., and Méndez, C. A., 2008: Applying a Simulation-based Tool to Productivity Management in an Automotive-parts Industry. In: *Proceedings of the 2008 Winter Simulation Conference* (Mason, S. J., Hill, R. R., Mönch, L., Rose, O., Jefferson, T., and Fowler, J. W., eds.). Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, 2005, p. 1838-1846.

Banks, J., 1998. *Handbook of Simulation*. USA, John Willey & Sons

Concannon, K. et al. 2007. *Simulation Modeling with SIMUL8*. Visual Thinking International, Canada 2007.

Law, A., 2000. *Simulation Modelling and Analysis. Boston (USA)*, MC-Graw Hill

Masood, S., 2006. Line balancing and simulation of an automated production transfer line, *Assembly Automation*, Vol. 26 Iss: 1, p. 69 – 74.

Montevechi, J. A. B., et al., 2007. Application of design of experiments on the simulation of a process in an automotive industry. *WSC'07 Proceedings of the 39th Conference on Winter Simulation*, IEEE Press Piscataway, NJ, USA 2007, p. 1601-1609.

O'Kane, J.F. et al., 2000. Simulation as an essential tool for advanced manufacturing technology problems. *Journal of Materials Processing Technology* 107/2000, p.412-424

Shalliker, J. and Ricketts C.: *An Introduction to SIMUL8, Release nine*. School of Mathematics and Statistics, University of Plymouth, 2002.

SIMUL8. 2012 SIMUL8 WEBMASTER. *Process Improvement with SIMUL8 Simulation Software*. Available from: http://www.simul8.com/about/ [accessed 10 April 2013]

SIMUL8-Clanky a pripadove studie 2013. Available from: http://www.simul8.cz/clanky-a-pripadove-studie [accessed 1 Jully 2013]

VLTAVA2000. 2012 In: Felicia, Available from: http://www.vltava2000.cz/interskoda/goods-047903015J-20-alternator-felicia-13-cz-047903015j-047903015j.html [accessed 13 April 2013]

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