Optimizing leather cutting process in Make-To-Order production to increase hide utilization

Giuseppe Fragapane[1], Oladipupo Olaitan, Erlend Alfnes and Jan Ola Strandhagen

Abstract. The growing trend of customization in the leather furniture industry has increased the need for many companies to switch from Make-To-Stock (MTS) to Make-To-Order (MTO) strategy. The shift to high-mix and low-volume presents new challenges for the production. This research presents concepts for the leather cutting process to increase the available calculation time for nesting and increase the selection for the nesting process, in order to maximize the hide utilization. The contribution to theory is a cutting process concept towards MTO in the leather industry.

Keywords: Leather cutting process, Nesting, Make-to-order

1 Introduction

Mass customization is one of the leading strategies in satisfying customers' needs, and a competitive strategy in today's markets[1, 2]. The growing trend of mass customization can be seen in the leather industry [3] and it enables companies to switch from MTS to MTO strategy. The MTO strategy enables companies to produce high variety of products in small quantities and satisfy the unique needs of their customers [4]. Companies benefit from the MTO strategy in terms of cost and profit due to lower inventory levels, maximum sales, elimination of material waste, flexible production and customer satisfaction [5]. The shift from MTS to MTO strategy and moving the Costumer Order Decoupling Point (CODP) upstream presents new challenges for production in the leather industries.

For the leather cutting, the amount of different shapes to cut of the leather hide increase immensely while the batch size reduces significantly. The more different shapes there are available to nest, the more possible constellations of nesting them on hides are possible. The number of possible constellation increases exponentially, and this calls for more process time to find the best fit of the parts on the hides. Generally, the more shapes there are to be nested, the better are the results for utilization and vice versa [6].

The efficient utilization of the leather hide has prime importance [7], which can be attributed to the fact that the cost of the leather hide often constitutes a significant pro-

[1] G. Fragapane (✉)
Department of Mechanical and Industrial Engineering,
Norwegian University of Science and Technology, Trondheim, Norway
e-mail: giuseppe.fragapane@ntnu.no

portion of the manufacturing costs, such that increasing its utilization provides significant cost savings[8, 9]. As a result, there have been a lot of attention in the leather industry to improve the nesting algorithms for determining how to fit variety of products onto hides [9-11]. Existing research have focused on developing algorithms that can determine the best possible ways to fit irregular product shapes and characteristics on raw hides, in order to achieve the best possible hide utilization within the shortest time possible [6, 9].

However, to most companies, the evaluation time and computational resources needed by these algorithms to deliver optimal results are not affordable [8]. This often leads to the acceptance of sub-optimal results for the hide utilization, and of results that do not suit pre-determined production plans.

This research investigates and presents possible methods to increase the time available for the nesting process in order to improve utilization. It analyses the interconnections between the manufacturing steps and proposes ways in which they can be re-organised. Its aim will be to address the question of how the nesting and cutting processes should be designed in order to maximize the hide utilization for high mix and low volume production.

The commonly used method will be compared with the suggested solution. The result of investigation will stimulate further research to optimize leather cutting process in order to maximize the hide utilization.

2 Literature review

2.1 Leather Nesting Problem

The roots of the Leather Nesting Problem derive from the cutting problem discussed in research since 1970s, in the metal, glass, wood, plastics, textiles and leather industries[10]. The cutting problem seeks to determine within given dimension the highest utilization of raw material through an heuristic approach [12]. The nesting problem is a two-dimensional cutting problem, which can occur in various production processes in leather industries [13]. Nesting is defined as "where more than one piece of irregular shape must be placed in a configuration with the other piece(s) in order to optimize an objective" [14]. The Leather Nesting Problem is one of the hardest two-dimensional cutting problems [9]. It allocates a set of irregular shapes within natural leather hides with highly irregular contours and heterogeneous interior due to holes and quality zones, in order to utilize most of the leather hide [9, 15]. Traditionally the nesting process is performed manually and results in low nesting efficiency and utilization rate of the material [13]. Surveys showed that automated in comparison to manual nesting and cutting results in higher utilization and shorter process time [6].

Many researchers focus on optimizing algorithms for nesting to increase the hide utilization [8, 13, 16-18]. Because of the high cost of leather, small improvements in hide utilization have a great effect on profitability [7]. However, nesting cannot been seen as an isolated mathematical problem. Several processes are also affected by the nesting process. Nesting is connected closely to logistic planning and order management [19]. Factors like due dates, batch size and setup time are connected and have to be considered. Consequently, the nesting problem and the scheduling problem have to be addressed simultaneously. Surveys show that advanced scheduling techniques in the leather industry lead to significant improvements in utilization, idle time, make span and tardiness reduction [20]. Not taking the correlation between planning, scheduling and nesting into account will decrease the material utilization and overall production objectives and activities [21, 22].

2.2 Leather Cutting Process

Nesting is one of the essential steps in the leather cutting process, which consists of the steps of (1) Quality Control (2) Scanning (3) Nesting and (4) Cutting, as shown in Figure 1.

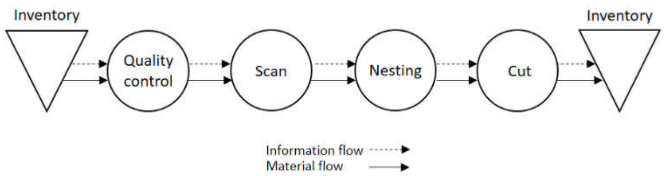

Fig. 1. Leather Cutting Process

Skilled workers have to set the hide on the machine and straighten the folds of the hide to a flat surface. In quality control, defects of the hides have to be identified and marked into zones. Because the range of defects is wide and various, automated defect detectors are still inefficient in identifying and evaluating the whole range of defects [23, 24]. Experienced workers can evaluate the defects best and assign them to five different quality categories of A, B, C, D and holes [9]. Scanning the hide reproduces an image with the contour of the hide. The image combined with the different quality zones is the basis for the nesting process. Shapes that will be nested on hides have different quality demands. For instance, the viewing and hardwearing areas of a leather furniture require the highest quality, whereas shapes with low visual areas can be allocated to lower quality areas. The nesting of the parts is a time intensive calculation operation due to the high number of possible constellations. The constellation with the highest hide utilization will be the template for cutting. The resulting template and, therefore, the contour of the parts are cut with a vibrating knife or a punching tool. In a last step, the cut parts are collected and forwarded to the next production process.

3 Process Reorganisation For Improved Leather Utilization

In this section, a concept is described for the reorganisation of the manufacturing steps, such that it enables to nest parts on several hides and decide with the support of an evaluation logic on the hide, which hide selection results in the highest utilization. The nesting process will be outside of the value adding time and thus more time can be dedicated to determining the best constellation.

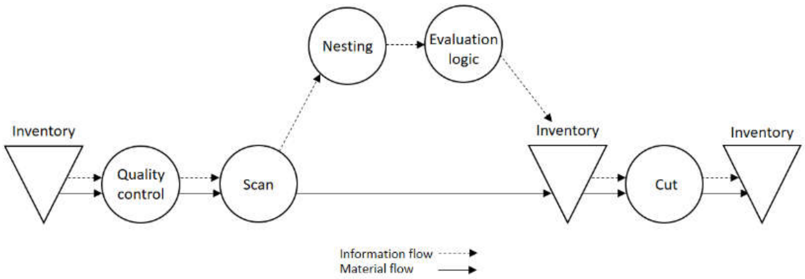

Fig. 2. Suggested Leather Cutting Process Reorganisation

As shown in Figure 2, the new arrangement of the process is divided in three main processes of (1) Preparing and storing the data and material, (2) nesting, evaluating and deciding on a hide and (3) cutting. In the first step, hides are quality checked and scanned. These hides receive an identification number and are stored. The information of the marked quality zones and the scanned layout of each hide are stored in a logical database. The data of the hides enables in a second step to nest the parts from a pool of orders on several hides and evaluate the utilization. This evaluation can be supported with different decision logics. Different decision support logics can be designed and applied, depending on the company's preference and the production demands. This research will propose and investigate three different decision logics, as described in the following paragraphs, and illustrated in Figure 3.

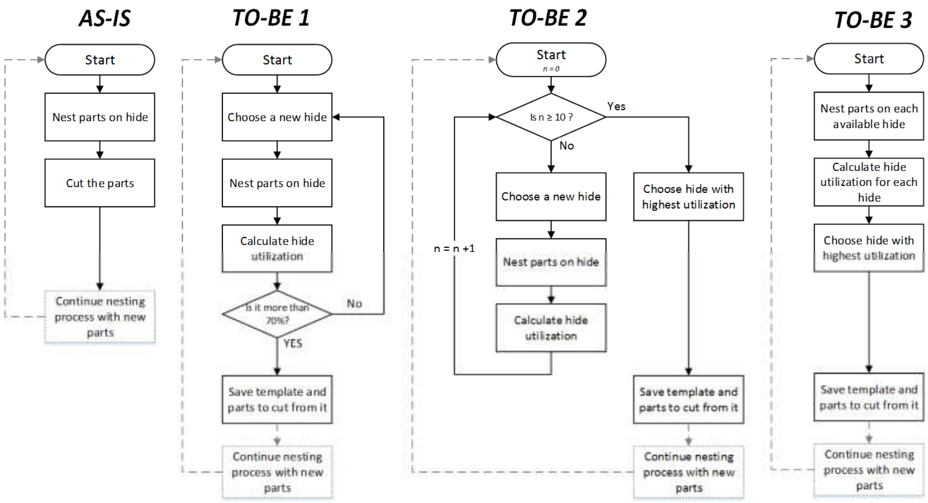

Fig. 3. Evaluation Logic

TO-BE 1: Select first hide, which reaches a minimum predefined percentage of hide utilization, for cutting. Parts are nested on different images of scanned hides. If a minimum predefined utilization, e.g. 70%, is passed, the template and hide are sent for cutting.

TO-BE 2: Select hide, which reaches the highest hide utilization, within a defined range of hides for cutting. Parts are nested on a range of different scanned hide images, e.g. 10. The template and hide that achieves the highest hide utilization are sent for cutting.

TO-BE 3: Select and cut the hide that achieves the highest utilization among all available hides. Parts are nested on all images of scanned hides. The template and corresponding hide that achieved highest in hide utilization are sent for cutting.

In the last step, the hides are released from inventory and positioned on the cutting machines. The identification number of the hide is used to select the corresponding template which is then used to cut the parts out of the hide.

4 Discussion, Conclusion And Recommendation

The main strategy in the leather industry has traditionally been mass production and MTS strategy. Mass production typically have fewer product variants which again results in less variety of part shapes. This tradition has formed the current knowledge and understanding of the leather cutting processes.

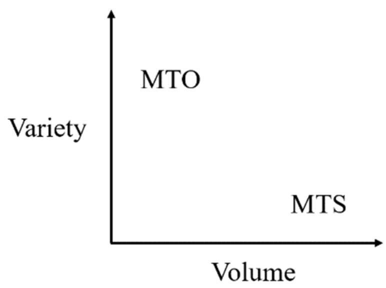

Fig. 4. Position of MTS and MTO in 'Volume vs. Variety' based on [4]

Low shape variety is unfavorable for hide utilization due to low possible nesting constellations. In MTS production, the batch size is kept large in order to use shapes several times in a nesting attempt. This way, the possible constellations and the leather hide utilization increase. Production planning can identify and define the batch sizes to meet short lead times and high hide utilization.

The larger the batch size and the lower the batch variety are, the less important the variety of the hides is. Considering several hides within the nesting process and in a nesting attempt is of minor significance in mass production and MTS production.

The shift to mass customization and MTO strategy changes the value chain and makes it necessary to investigate and rearrange the processes. Since the leather parts are customized and the CODP moves upstream into leather cutting process and changes it from a forecast-driven to a customer-order driven process. The switch to customer-order driven process affects the batch size and parts variety significantly. The batch size decreases while the variety of the shapes to be cut increases. High variety in shapes results in more combinations and constellations in the nesting process and, consequently, more time is needed to calculate them. At the start of the nesting process, a wide choice – which is favorable – is available; however, towards the end of the batch and process, only less and complex parts are available. The utilization differ significantly between the beginning and end of a batch.

Combining similar orders to increase the batch size could lead to similar hide utilization results as in MTS production. Orders must be buffered and grouped. This will result in a high-mix production to an increase of throughput time and longer delivery dates. Long delivery dates reduce the competitiveness in today's markets. More flexibility is needed for a MTO production to hold a constant and high utilization.

This research presented a new arrangement of the cutting process and allocated the nesting process outside of the value added time to increase the available calculation time. This allows the nesting process to calculate more different constellations and combinations of the shapes onto several hides. Considering more hides in the process increases the probability of achieving higher hide utilization. Complex shapes and hides with poor quality can be used in several nesting attempts and so increase the chances of achieving higher utilization. This arrangement can take in consideration small batches and high variety.

The evaluation logic can be adjusted to the production demands. Each evaluation logic influences the hide utilization, but also the inventories and process time. The amount of hides taken in account in the evaluation logic will define the size of the inventory and the time needed for nesting. The more strings are included in the evaluation logic, the more resources, for instance inventory space, IT support or servers, will be needed.

	Hide utilization	**Process time**	**Inventories**
TO-BE 1	3	2	2
TO-BE 2	2	1	1
TO-BE 3	1	3	3

Comparison of logic with each other (1=best, 3=worst)

Table 1. Ranking Of Logics

TO-BE 1 is ideal, if the hide utilization has to achieve a minimum and be constant. The challenge will be to determine the minimum hide utilization. Setting the limit low, satisfactory results can be expected in a short calculation time. Setting the limit high can result in an endless process.

TO-BE 2 finds the best hide utilization within a range of hides. Determining the range of hide for evaluation will define process time and needed inventory. Both will be constant which is favorable for planning and scheduling.

Considering all available hides in the nesting process is challenging due to the nesting process time. TO-BE 3 can be applied, if the benefit of the hide utilization justifies the long process time. This can be the case for low volume and exceptionally high raw material costs.

The new arrangement of the process and the proposed evaluation logic will significantly improve hide utilization. However, these changes imply more and new process steps and more handling of the hide. These changes can be justified, if the higher utilization of the hide and resulting savings would cover the additional costs.

Future research will be aimed at further developing the evaluation logics, in order to keep the process time and inventories low.

5 Acknowledgment

This research has been carried out as part of SØM4.0 project, as funded by the Norwegian Research Council's BIA programme. The authors wish to thank the project partners for facilitating this work.

6 References

1. J. Daaboul, et al., "Design for mass customization: Product variety vs. process variety". CIRP Annals-Manufacturing Technology, 2011. 60(1): p. 169-174.
2. G. Da Silveira, D. Borenstein, and F.S. Fogliatto, "Mass customization: Literature review and research directions". International journal of production economics, 2001. 72(1): p. 1-13.
3. L. Barnett, S. Rahimifard, and S. Newman, "Distributed scheduling to support mass customization in the shoe industry". International Journal of Computer Integrated Manufacturing, 2004. 17(7): p. 623-632.
4. M. Stevenson, L.C. Hendry, and B.G. Kingsman, "A review of production planning and control: the applicability of key concepts to the make-to-order industry". International Journal of Production Research, 2005. 43(5): p. 869-898.
5. D. Pollard, S. Chuo, and B. Lee, "Strategies for mass customization". Journal of Business & Economics Research (Online), 2016. 14(3): p. 101.
6. I. Elamvazuthi, S. Kamaruddin, and M.S. Azmi, "Automation of nesting and cutting processes of leather furniture production: a case study". International Journal of Mechanical & Mechatronics Engineering, 2008. 9(10): p. 25-29.
7. A. Crispin, et al., "Genetic algorithm coding methods for leather nesting". Applied Intelligence, 2005. 23(1): p. 9-20.
8. R. Baldacci, et al., "Algorithms for nesting with defects". Discrete Applied Mathematics, 2014. 163: p. 17-33.
9. C. Alves, et al., "New constructive algorithms for leather nesting in the automotive industry". Computers & Operations Research, 2012. 39(7): p. 1487-1505.
10. H. Dyckhoff, "A typology of cutting and packing problems". European Journal of Operational Research, 1990. 44(2): p. 145-159.
11. A. Elkeran, "A new approach for sheet nesting problem using guided cuckoo search and pairwise clustering". European Journal of Operational Research, 2013. 231(3): p. 757-769.
12. K.A. Dowsland and W.B. Dowsland, "Packing problems". European journal of operational research, 1992. 56(1): p. 2-14.

13. Y. Huang, et al. "Research on an intelligent leather nesting system". in ICMIT 2005: Merchatronics, MEMS, and Smart Materials. 2005. International Society for Optics and Photonics.
14. J.A. Bennell and J.F. Oliveira, "The geometry of nesting problems: A tutorial". European Journal of Operational Research, 2008. 184(2): p. 397-415.
15. A.J. Crispin and K. Cheng. "Backtracking Greedy Algorithm for Cutting Stock Problems". in Applied Mechanics and Materials. 2008. Trans Tech Publ.
16. Z. Yuping, J. Shouwei, and Z. Chunli, "A very fast simulated re-annealing algorithm for the leather nesting problem". The International Journal of Advanced Manufacturing Technology, 2005. 25(11-12): p. 1113-1118.
17. A. Uday, E.D. Goodman, and A.A. Debnath. "Nesting of irregular shapes using feature matching and parallel genetic algorithms". in In. 2001. Citeseer.
18. J. Heistermann and T. Lengauer, "The nesting problem in the leather manufacturing industry". Annals of Operations Research, 1995. 57(1): p. 147-173.
19. L. De Vin, J. De Vries, and T. Streppel, "Process planning for small batch manufacturing of sheet metal parts". International Journal of Production Research, 2000. 38(17): p. 4273-4283.
20. A. Habib, K. Jilcha, and E. Berhan. "Performance Improvement by Scheduling Techniques: A Case of Leather Industry Development Institute". in Afro-European Conference for Industrial Advancement. 2015. Springer.
21. G. Chryssolouris, N. Papakostas, and D. Mourtzis, "A decision-making approach for nesting scheduling: a textile case". International Journal of Production Research, 2000. 38(17): p. 4555-4564.
22. T. Sakaguchi, et al. "A scheduling method with considering nesting for sheet metal processing". in ASME/ISCIE 2012 International Symposium on Flexible Automation. 2012. American Society of Mechanical Engineers.
23. Y.-C. Chiou, "Intelligent segmentation method for real-time defect inspection system". Computers in Industry, 2010. 61(7): p. 646-658.
24. C. Yeh and D.-B. Perng, "A reference standard of defect compensation for leather transactions". The International Journal of Advanced Manufacturing Technology, 2005. 25(11): p. 1197-1204.