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Integration of Computer Integrated Manufacturing for reducing waste and improvement of productivity in Nepalese shoe manufacturing industry

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Abstract

Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities to integrate design, manufacturing and associated business functions to reduce the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component [1]. This research focuses to integrate a part of CIM by application of Computer Aided Design (CAD) for reduction of the waste (i.e., time and material) by reducing the design cycle time and removing the necessity of making prototype for every modification during design cycle. Also, this research is done to reduce the extensive manual works that has been taking place in Kiran shoes manufacturers for decreasing the possible human error. Current design process is studied with time-motion analysis, accuracy with production. CIMS integration model is proposed and comparative analysis between the current design process with the CIMS integrated process is done. The integration is proposed in two phase where integration of first phase (integration of software for automatic nesting) showed reduction of time by 74.47%, more accuracy, productivity improvement by 18.51% in one part. Similarly, the second phase (integration of software for preliminary design and modification) reduced the design time by 47.21% which leads to reduce costs and helps to get to market faster.

Keywords

Computer Integrated Manufacturing (CIM), Computer Aided Design (CAD), Computer Aided Machining (CAM), Footwear, Shoe Design, Nesting, Waste reduction, Productivity

1. Introduction

With increasing choices, growing fashion consciousness and rising health awareness, the global demand for footwear has been increasing. The global footwear market has been steadily increasing, with production reaching 22 billion pairs in 2013 and new importers rapidly entering the global market [2]. According to the World Footwear Yearbook 23,000 million pairs of footwear (all product groups) were produced in 2015 of which 82% were from Asian countries, led by China (59%), India (10%) and Vietnam (5%). Nepal production is still down on the list [3].

Footwear manufacturing in Nepal is a challenging field as it is surrounded by India and China which are major competitors in the global market regarding price, design, quality and volume [2]. The sector has had uneven growth over the years due to longstanding weaknesses in the adoption of new technology, poor infrastructure, shortage of power, stalled political process, difficult trading conditions, global competition and global economic downturn [4]. Most Nepalese enterprises do not have sufficient understanding and capacity to promote their product and interact with international companies [5].

Regarding the domestic footwear market of Nepal, 42% is covered by Nepalese footwear, whereas 58% is covered by imported footwear [2]. Among the total footwear produced in Nepal, 71.36% of the final consumers are Nepalese and 28.64% are international consumers [2]. With an exception of the fiscal year (FY) 2015/16, the footwear export has steadily been growing. In FY 2014/15 the export volume was 8.6 million pairs, a significant growth compared to 6.3 million pairs in FY 2011/12. This sector is contributing towards narrowing down the trade deficit of the country [6]. Nepal Trade Integration Strategy (NTIS) has identified footwear as one of the export potential products and targets to increase production from 30 million pairs to 45 million pairs and increase exports from 7.8 million pairs to 12 million pairs by 2020 [7].

The competition in footwear industries regarding cost, quality, reliability, etc., has pushed companies to improve their products developing urgency to implement better system to produce quality product in low cost . Kiran Shoes manufacturers also has been facing the same challenge in the recent years. Some main reasons for the need for improvement are as follows:

1. In the international market, the Nepalese sector will find it difficult to compete with the big Asian countries (China, Vietnam, India, Thailand or Indonesia) [3].
2. Increase of local manufacturers for shoes in Nepali market [2].
3. Increment of labor cost according to new labor act 2074 (NBSM, 2017) has forced company to reduce the process cost in order to keep the price of the product constant.
4. Nepali footwear are more expensive than footwear imported from India and China [3].
5. Growing availability of mass-produced footwear offered by Internet sellers [3].
6. Need for continuous improvement for sustainability.

Kiran Shoes Manufacturers Pvt. Ltd. (KSM), one of six large manufacturers of footwear in Nepal, uses reverse engineering followed by suitable modification according to inhouse last to design their shoes. The designing in KSM was done manually in previous days but since 2018, a CAD software, Delcam Crispin Engineer, has been implemented for the improvement of design. The integrated CAD has somehow improved the productivity of the designer for cutting patterns but still involves huge amount of manual work. The output from the software is followed by iterative process of making prototype, verification and modifications if needed. Nesting process for blanking which is all done manually defines the material used per pair. Nesting process involves the process of drawing of character lines on graph paper and arranging it manually which takes a lot of effort, time and accuracy. The norms (length of roll consumed by each part in pairs) obtained via manual nesting is passed to procurement and material and resource planning is done taking the provided data as a reference.

The implementation of CAD allows the process to be done in a scientific way rather than manual way. The accuracy and work flow could be greatly improved giving designer flexibility to update design, modify and analyze data in shorter time which reduces waste of both time and material. In addition to this, it becomes easier to approve shoe design via 3D data created with real time modification.

2. Computer Integrated Manufacturing

Computer Integrated Manufacturing(CIM) includes the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. The data required for various functions are passed from one application software to another in a seamless manner. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory or a manufacturing facility. CIM reduces the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component. CIM stands for a holistic and methodological approach to the activities of the manufacturing enterprise in order to achieve vast improvement in its performance [1].

The main benefits can be classified into three kinds as listed below:

1. Reducing inventory and work in progress
2. reduction in design as well as production time.
3. Improving production efficiency
4. Improving product quality
5. Reducing cost
6. Improving product design ability
7. Standardizing processes
8. Optimizing processes
9. Improving market response ability

Introducing a new technology in any enterprise can lead to reduced operating costs, decreased labor cost and consequent decrease in unit costs [8]. In a research for designing machine tool, CIM had produced an increase of productivity of 40-70%. Both design costs and the in-shop time of a part were reduced by 15-30% and 30-69% respectively. Scrap was also reduced by

20-50%, leading to better product quality [9]

Past researches shows that Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) are one of the most effecting and influencing technology that can the added in a manufacturing industry for its improvement [10]. The needs on shoe market change today faster than ever. The shoe series are therefore smaller and the new shoe models have to be developed faster [11]. This need of speed cannot be obtained by the classical manual process which can only be achieved by CAD/CAM. There is no doubt that physical samples of shoes will always be produced, but the use of virtual shoes should mean that less are rejected and that more variations (i.e. choice) can be offered to buyers resulting in quicker time to market and lower costs [12].

Some examples where CAD/CAM are applied shows productive results. Boeing 757 was completely designed by CAD which resulted assembly time reduction from 10 days to 2 days and also, reduced the bumber of working prototype from 10 to 3 [13]. Similarly, Cannondale claimed that “CAD/CAM technologies enabled it to produce five times as many bicycles per year with the same floor space. CAD/CAM also enabled the firm to redesign 90-95 percent of its 37 models each year” [13].

Computer Aided Design and Computer Aided Manufacturing is the way things are made these days. Without this technology we wouldn’t have the range and quality of products available or, at least, they wouldn’t be available at a price most of us can afford.

3. Reference Model for Analysis

Figure 1: Article 032, Article JB-3

The current system of how process flows for manufacture of shoe is studied. Model is selected based on following process.

1. Popularity of the model
2. Production volume
3. Effectiveness of the improvement
4. Recommendation from the management

Models selected: Article 032 (Size-8, Grey and Black), JB-3 (Size-8, Black)

4. CAD/CAM Software for Integration

According to the designer, Delcam Crispin engineer has been in use for a year which is used to smoothen line, separate parts and grade different size. Hence, software of same tree has been chosen to implement for compatibility. Designer also knew about Delcam Crispin ShoeCost, hence, was selected as CAD to be implemented.

4.1 Delcam Crispin Shoemaker

Shoemaker produces realistic 3D digital models which allows to approve designs in less time and reduces the need for expensive physical prototypes. Benefits of this software are as follows:

1. Select new designs quickly with realistic 3d digital models
2. Reduce pattern development time by generating an accurate 2d pattern
3. Minimize physical sample costs by rendering
4. Create more variation for buyers
5. Use with most cad systems

Figure 2: Article 032 rendered image via Keyshot

4.2 Delcam Crispin Shoecost

Shoecost provides the tools needed to nest the parts, yielding norms for cost calculation and material planning. Benefits of this software are as follows:

1. Accurate costing quickly
2. Stay within your target cost
3. Maximize material yield by automatic nesting
4. Use with the existing patterns
5. Easily customize to meet the needs

Time-motion study is done for design, nesting and calculation or norms of 032 article by current method and by using CAD for comparison. In addition to this, accuracy is compared by comparing the pairs estimated by the current norms, norms calculated by CAD and the actual production. By analyzing the nesting layout, the blanking is modified if possible. Current model JB-3 is also taken for checking the accuracy of CAD.

5. Result and Discussion

The designing process is mainly divided in three phases.

5.1 Phase I: Creating a standard flattening profile for the standard last

In this phase, the rigorous manual process has to be done to obtain the flattened surface from the curvature of last. This phase completely depends upon the knowhow of the designer. The CAD software will perform flattening automatically with accurate result reducing the dependency on the know-how of the single designer rather implementing the scientific process for flattening.

Table 1: Time taken for flattening surface of a standard last

SN	Task	Time (hrs.)
1	Tape wound over the standard last	1
2	Approximate median line over the last based on experience	1
3	Cut the tape in half and paste it in 2D sheet as a developed surface	1
4	Develop a standard flattened surface for the last	1
	Total	4

5.2 Phase II: Designing and prototyping the shoe

In this phase, complete designing of the shoe from reverse engineering to prototype building is done guided by iterative process in which prototype has to be made during each iteration.

Table 2: Time required for Designing of shoe according to current process

SN	Task	Time (hrs.)	Time after iteration -3X(hrs.)
1	Draw the character lines according to design on the developed surface	1.5	1.5
2	Scan and line setting (smoothing line)	1.5	1.5
3	Separate the parts	2	2
4	Modification	3	6
5	Sample parts are cut by using CNC	0.16	0.48
6	Material selection	2	2
7	Upper part prototyping	6	18
8	Sole attachment	1	3
	Total time per design	14.16	34.48
	Total design per month	6	
	Total time (hrs.) per month	84.96	206.88
	Total time (days) per month	10.62	25.86

Table 3: Time required for Designing of shoe according to CAD software

SN	Task	Time (hrs.)	Time after iteration -3X(hrs.)
1	Draw the character lines on 3D model the developed surface	1.54	1.54
2	Scan and line setting (smoothing line)	1.5	1.5
3	Separate the parts	0	0
4	Modification	3	6
5	Sample parts are cut by using CNC	0.16	0.16
6	Material selection	2	2
7	Upper part prototyping	6	6
8	Sole attachment	1	1
	Total time per design	12.2	18.2
	Total design per month	6	
	Total time (hrs.) per month	73.2	109.2
	Total time (days) per month	9.15	13.65

Improvement from application of CAD: 47.21%

decrement of time required to process one design to be manufactured.

Total design that can be processed per month if CAD is integrated: 11 designs (sssuming 8 hrs. working hour)

Iterations are done until the management verifies the shoe whether further modifications are done or the production can be continued.

5.3 Phase III: Nesting process for planning, cost and production

In this phase, the nesting layout is done where the pattern for cutting the part out of the roll is decided. Currently all the nesting process is done my manual process using CNC printed template and graph paper. This process decides waste generated from each part and the upper part cost. Design modifications can be done where possible to obtain minimum waste.

This process generates the norms which is passed to costing and planning department based on which material planning, procurement and cost calculation is done. Main things to be considered during nesting are the fabric direction and pattern in the fabric.

Table 4: Comparision of time required for nesting 032 by manual and CAD software

SN	Components	Time(min)	
		Manual	CAD
1	Toe Cap Rexine &Back Tab	7.8	1.442
2	EyeStay Rexine	5.5	0.358
3	Counter Rexine	5.5	0.025
4	Back Trimming	5.5	7.642
5	Quarter Trimming	5.5	0.025
6	Vamp Mesh	7.3	0.408
7	Quarter Mesh	7.8	3.925
8	Tongue Mesh	4.5	0.025
9	Collar Lining	6.1	1.825
10	Stiffener	5.5	0.025
	Total	61.5	15.7

Time reduction from 61.5 min to 15.7 min has been achieved by application of software. Reduction of the nesting time has been reduced by 74.47%.

In order to compare accuracy of the nesting difference between the actual production and current norms is calculated. Similarly same process is repeated with the norms produced by the software.

Table 5: Comparison of actual production of 032 with current production estimation and CAD

SN	Components	Pairs per meter		
		Manual	CAD	Prod.
1	Toe Cap Rexine &Back Tab	28.0	31.6	32.8
2	Eyestay Rexine	83.3	86.1	85.8
3	Counter Rexine	58.8	63.9	64.8
4	Back Trimming	66.0	67.3	67.0
5	Quarter Trimming	84.0	72.4	78.0
6	Vamp Mesh	39.5	40.5	41.4
7	Quarter Mesh	17.5	16.7	17.1
8	Tongue Mesh	71.4	77.9	78.1
9	Collar Lining	27.8	42.5	44.0
10	Stiffener	55.0	70.0	69.8

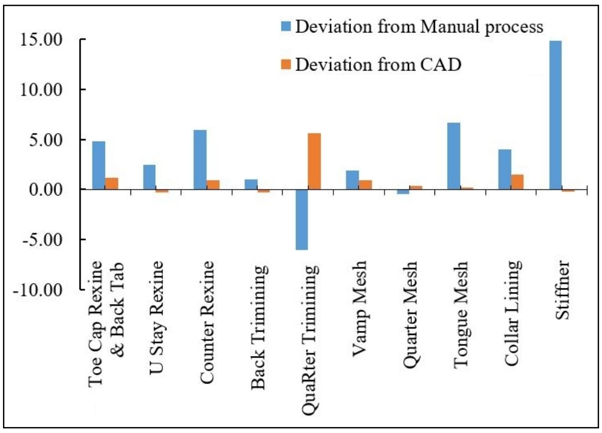

Figure 3: Deviation of 032 parts from actual production

Taking zero deviation as standard, Standard deviation from current process: 6.21 and CAD: 1.93 is obtained.

Table 6: Comparison of actual production of JB-3 with current production estimation and CAD

SN	Components	Pairs per meter		
		Manual	CAD	Prod.
1	Vamp + Tongue top Rexine	25.0	24.5	25
2	Eyestay Rexine	48.7	54.4	60
3	Mudguard Rexine	50.0	57.6	59
4	Counter Rexine	48.7	51.8	51
5	Collar Rexine	55.0	51.0	51
6	Quarter Mesh	10.7	12.7	11
7	Tongue Mesh	37.3	42.0	43
8	Vamp Lining	34.2	35.2	41
9	Collar Lining	17.7	18.0	20
10	Stiffener	58.0	68.1	68

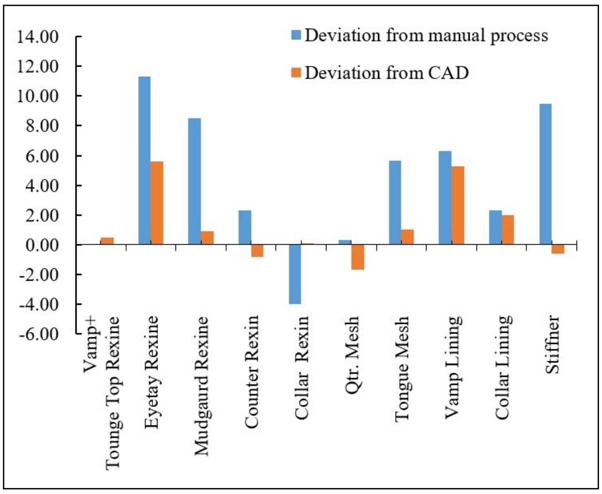

Figure 4: Deviation of JB-3 parts from actual production

Taking mean difference of zero from production, standard deviation for current process and CAD is calculated. Standard deviation from current process: 6.240 and CAD: 2.63 is obtained.

The blanking layout was compare with the production to find whether there are areas for improvement. The layout of all parts except Quarter mesh was different. After application of the more efficient layout, production of quarter mesh has increased from 11 pairs to 13.5 pairs

Table 7: Material saving by application of layout as set by ShoeCost

SN	Title	Qty (hrs.)
1	Length of material used by a pair according to current layout	0.091 m
2	Length of material used by a pair according to current layout	0.074 m
3	Total production in from Shrawan 2075- Poush 2075	116945 pairs
4	Total material used for production according to current layout	10631.36 m
5	Total material used for production according to improved layout	8662.59 m
6	Material saved	1968.77 m

Productivity improvement of 18.51% in one part of JB-3 has been achieved

As there is difference in the data provided by designer used for planning and actual production, the material could be short or can be excess which will create a huge unbalance on the inventory in both models.

6. Integration

For smooth integration of CIM in any enterprise, the process to be integrated should properly blend in the workflow. Delcam Crispin Engineer is currently in use for making patterns and grading. Delcam Crispin Shoemaker and Delcam Crispin ShoeCost is selected in such a way that it fits the current pattern of work. Implementation of the any one or both is possible without any complication. By implementing this software, all the manual and experience based process could be replaced by automatic and scientific process delivering comparatively lesser design time and improved accuracy yielding less waste and high productivity. As the main target of this thesis is to implement CIM in the design phase for less waste and high productivity, integrating both software could be a best option. However, integration of one followed by another could be one option providing the designer to learn enough time to properly implement each software.

6.1 Integration Phase I: Integration of Delcam Crispin ShoeCost

The software has been tested for the two articles, 032 and JB-3. The results from the application of CAD are listed below.

1. Compatible with current system.
2. Manual work completely changed to software based scientific method decreasing human error.
3. Reduction of time to 74.47% lesser.
4. More accurate data obtained with less deviation form production.
5. Less inventory due to improved accuracy during planning.
6. Improved productivity by 18.51% in 6 months in one part of JB-3 article.
7. Less waste in time and material.

6.2 Integration Phase II: Integration of Delcam Crispin Shoemaker

The software has been tested for 032 article. The results from the application of CAD are listed below.

1. Compatible with current system.

2. Flattening of the shoe last surface is done automatically via scientific way rather manual process reducing possible human error.
3. Reduction of time to 47.21% lesser.
4. Parts are already separated and aligned reducing process of separating and aligning parts.
5. Real time visualization of the model for easy modification and confirmation.
6. Reduction in prototype making in every phase of iteration reducing time to make one and sample costs.
7. Easy modifications in the physical model.

7. Conclusion

The current design process in Nepalese shoe manufacturing industry is compared with the CIM integrated process. The result shows great reduction of waste in the overall process. 74.47% reduction in time was obtained for the process of nesting, calculating norms by implementation of CAD/CAM software. Similarly, 47.21% reduction of time was obtained for the designing process by the integration. Material waste is also reduced as the need for physical model in earlier stage of design is replaced by virtual model. The data comparison of manual process, CAD and actual production shows that CAD gives more accurate data. Though the productivity depends upon how the process is done, application of CAD/CAM software will push for improvement. Betterment of 18.51% in productivity was found in one part of JB-3 article. The integration of CIM reduces the design time allowing frequent release of new designs in the market. In addition to his, documents to transfer to procurement, production, planning and costing can be obtained from the software.

8. Recommendation

There are many areas in CIM other than CAD/CAM. Research on the integration of other aspects of CIM like Computer Aided Process Planning (CAPP), Manufacturing Resource Planning, CNC machine integration can add to improve productivity and reduce waste to current integration of CAD/CAM.

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