2016

Manual Versus Automated Drawing Checking: A Case Study

Thirupathi Reddygari

Manual Versus Automated Drawing Checking: A Case Study

MANUAL VERSUS AUTOMATED DRAWING CHECKING: A CASE STUDY

Industrial Technology

Non-Thesis Research Paper

A Research Paper for Presentation to the Graduate Faculty of

The Department of Industrial Technology

University of Northern Iowa

In Partial Fulfillment of the Requirements for

The Non-Thesis Masters of Science in Technology Degree

By

Thirupathi Reddygari

Nov 1, 2016

Approved by:

Nageswara Rao Posinasetti

Signature of Advisor

Date: 12/6/2016

Douglas R. Hotek

Signature of Second Faculty Professor

Date: 12-6-2016

1 Table of Contents

2 Introduction

Engineering drawing, a type of technical drawing, is used to fully and clearly define requirements for engineered items. The sketches or graphics communicate information from one mind to another; drawing consists of various geometric elements and textual data (Jozef V, 2014). In industry there are various types of drawings created for different applications such as product, assembly, machining, welding, hydraulic schematic, electrical schematic, Printed Circuit Board (PCB). After initial release of drawings, checking drawings for further release would be immense task depending on complexity of drawing. Checking smaller drawings (A4 size) won't consume greater time and effort, but larger drawings with multiple sheets would needs hours, days and sometimes demands group of people's effort to go through every bit of drawing. In the checking process, often checker gets distracted from his/her attention and forgets where he stopped. If the drawing is large with multiple sheets and if checker does not find any errors or mistakes in first couple of sheets, checker starts to gain confidence on drawing and begins to lose focus and starts to believe drawing was done with no misstates. Ignoring any piece of information on drawing would turns out to be costly affair. Mistakes that are not spotted will be carried over and parts may also manufacture to the unintentional dimensions. Errors could be expensive depending on complexity of part or product and fixing the mistakes on products is not as easy as fixing errors on drawing paper. Single incorrect part could lead to suspending entire production until the issues are resolved which would be costly deal for industry and its reputation due to delays. Catching errors or mistakes in early stage would save from future catastrophic situations. Another way of checking drawings is with help of software. The use of CAD results in safer, more productive, and more cost-effective (Marcus, Mauri, Haroldo, 2014). There are some complications with checking the drawings using CAD software (CreoView MCAD).

The MCAD software is capable of comparing drawings with DXF, DWG file formats. CAD files of both initial revision and future revision must be converted to DXF/DWG file format, then open both files in MCAD software. The software is capable of overlaying both drawings based on the sequence or revision. Detecting errors is essential since the 3D model will be used for 3D printing of prototype parts (Sinisa, 2015).

The purpose of research is to conduct comparative study of manual drawing checking method over automated drawing checking and propose best drawing checking solution.

2.1 Literature survey

2.1.1 Introduction

The purpose of this literary review is to gain insight into drawing checking process and how the drawing are created from parametric models or feature based models. With global competition, it is important for any industry that design, build and manufacture products with no mistakes, to remain competitive in their respective markets.

At this time in the public domain, it is difficult to find information related to the comparison of drawing methods, and there is little information on how CAD drawings are generated from 3D models and exported to DXF/DWG file format. Consequently, the literature will be reviewed in the following three complementary areas: Effects of modeling practices, Parametric Modeling and drawing.

2.1.2 Origins of CAD and parametric modeling

CAD is a set of techniques, each with its own advantages and restrictions (J Shah 2001). When CAD was introduced, there was resistance from designers and engineers because the program was difficult to use (J Shah 2001). CAD became popular after introducing parametric design method. Three dimensional (3D) models, allow designers to create complex geometries that can be moved, rotated, enlarged, and modified. When creating a 3D model, a CAD designer may first construct the basic shape of the object with sketches, 2D constraint based sketching will be created independently, to support tolerances in CAD (Hillyard, Braid 1978. Light, Gossard 1982). Feature based modeling will reduce number steps by reusing sketches and references (J Shah 2001). When feature dependencies are adequately constrained, alterations performed to a parent feature will automatically propagate to its child features, thus CAD model will react to its changes in a predictable manner (Bodein Y, Rose B, Caillaud E. 2014). The general goal of an efficient parametric modeling methodology should be to build design trees that are simple, easy to understand, and with a small number of parent/child dependencies that properly convey design intent (Wang Y, Nnaji B. 2005). Once the model is complete, 2D drawing will be generated from 3D model. Any changes does occur to parent feature will have impact on child node, so lack of modeling constraining skills can have impact on dependent or child nodes and relevant drawings.

2.2 Statement of the problem

Is automated checking process better and efficient than traditional checking process and uncover unintentional changes made to the drawings?

This drawing checking procedure is developed for revision related changes only. Main issue is that, manual check process won't cover all parts of drawing, once an updated or revised drawing arrives from a designer or drafter, the engineer has to scan through entire drawing in order to capture all intended modifications. However product or part geometrical models are created in

3D format are generally designed and constrained with other features of the model, when designer intention is to change a particular area or a feature, there are greater possibilities for changing other dimensions due to inter-related construction of model (Mario 2009). It is quite likely that, others may have made changes to the model, such un-intentional changes will be transferred over to drawing are not paid attention during drawing checking process.

2.3 Statement of purpose

To conduct research to reduce drawing checking time, uncover un-intentional changes and increase checking speed by implementing an efficient manual check method or by use of a software.

2.4 Purpose of the study

To implement best possible solution for drawing checking process by comparing manual checking process over automated checking. Conduct research to filter unwanted changes done to the parts or products.

2.5 Statement of need and justification

The 3D parts are modeled as per designer's expertise of product, manufacturing and CAD modeling software. In many cases engineers give directions to designers but not to the extent of constructing the 3D model. The responsibility of creating efficient models that can be easily altered and reused still lies with designer (Bodein, 2014, Leahy, 2013). Lack of designer knowledge or an outcome of modeling deficiencies turns out into mistakes. Certain features of CAD models are constrained; if a designer is interested in changing particular part geometry may have impact on children features tied to it, in such cases designer must check back all relevant dimensions or geometries, if not such un-intentional changes will be transferred over to drawing.

Engineer may or may not be interested in checking entire drawing, if he does then there are greater possibilities for catching un-intentional dimensional changes, if not drawings will be released with mistakes. The mistakes are going to be costly; as the parts are manufactured per drawing will not serve the form, fit and function.

The research must be conducted to uncover un-intentional changes and speedup checking process. There appear to be no ethical problems related to confidentiality, risk, or deception. A final justification is that no research has been reported especially on the checking of drawings using CAD software.

2.6 Summary

This chapter summarizes drawing checking process, impact of un-intentional changes and issues that were to be addressed to help implement an efficient checking method. It also lays the foundation for the rest of the research study.

3 Hypothesis

The drawing checking method using CAD software is more efficient than traditional or manual checking method?

4 Method

4.1 Assumptions of this study are:

a. The drawing check is been performed using appropriate soft copy files.
b. Ensure subjects understand and follow training provided for new checklist and use of CAD software.

c. The reduction in check process will be result of implementing new checklist and use of CAD software or traditional.

d. The improved checking process could be the result of implementing new checklist and use of CAD software or traditional.

e. No significant changes will made to the drawings that impacts checking time.

4.2 Limitations of this study are:

a. The results of this study are limited for engineers and designers.

b. The study does not include all engineering drawing standards.

c. The study is intended to show the results of comparison between manual drawings checking method over CAD software.

4.3 Statement of Procedure

This research is carried by experimental study. Experimental research enables researcher to manipulate the independent variable and establish cause-and-effect relationships among the variables. The subjects selected for these studies are engineers and designers who are extensively involved in dealing with drawing release in day to day life. Both participating expertise are chosen because of their different work profile, experience and subjects are willingness to participate in the study.

4.4 Definition of Terms

CAD (computer-aided design), is a software used to create two-dimensional (2D) drawings or three-dimensional (3D) models.

DXF (Drawing Exchange Format), is a CAD data file format enables data interoperability between CAD programs.

DWG is a proprietary binary file format used for storing two- and three- dimensional design data and metadata. It is the format for several CAD packages including DraftSight, AutoCAD.

CreoView MCAD, is a suite of digital mockup and product visualization software application. MCAD is an additional tool to enhance and improve the design checker role.

4.5 Outline of Procedure

Subjects from engineering and designer role are selected for this study. Identified forty participating subjects, 20 engineers, and 20 designers, with an average experience of 8 years, then groups are formed with 4 in each (2 engineers and 2 designers) to be able to conduct the test effectively and convenience. Subjects are trained with checking guidelines and use of CAD drawing compare software CreoView MCAD. Subjects are assigned manual checking and the CAD software treatment group with an identification numbers. The drawing was selected based on perception of average complicated part with 3 pages (A3) size drawings. The independent variable in this study is traditional checking and automated checking activity, the dependent variable is drawing errors.

The design group led will proctor the traditional checking group and the researcher or I led the automated (CAD software) checking group. The subjects in the traditional or manual checking treatment groups will be given two sets of drawings with three pages each, one being existing drawing and other being revised drawing with few known changes, while subjects in the automated group will be also given two sets of drawings in CAD format. Both groups will be given the same four drawing sets in two different formats. By having the subjects check the drawings will be monitored to record time taken to turn the drawing back, in the next round groups would switch the roles from traditional to automated and automated to traditional. The groups will be then served with same 4 sets of drawings. Researcher will record times of each subject when they are done with their assigned drawing check. Each time study and error information will be documented. The overall treatment was the same for both groups, thus eliminating a variable that may otherwise influence the results, the numbers of replications or how many times the experiment will be repeated to ensure that the results are consistent.

Subjects are given an existing released (Revision 00) drawing marked with changes in red to be done to the drawing, another set of same drawing with changes reflects in next Revision (01). The subjects are required to check and make sure that all marked changes, as shown in Figure 1, are done on new revision (01) drawing, as shown in Figure 2. The data collection tables, metrics, checklist and statistical calculations will be published below.

Only first sheets of the drawings LINK CASTING REV-00 and LINK CASTING REV-01 are shown here, all three drawing sheets are shown in Appendix C.

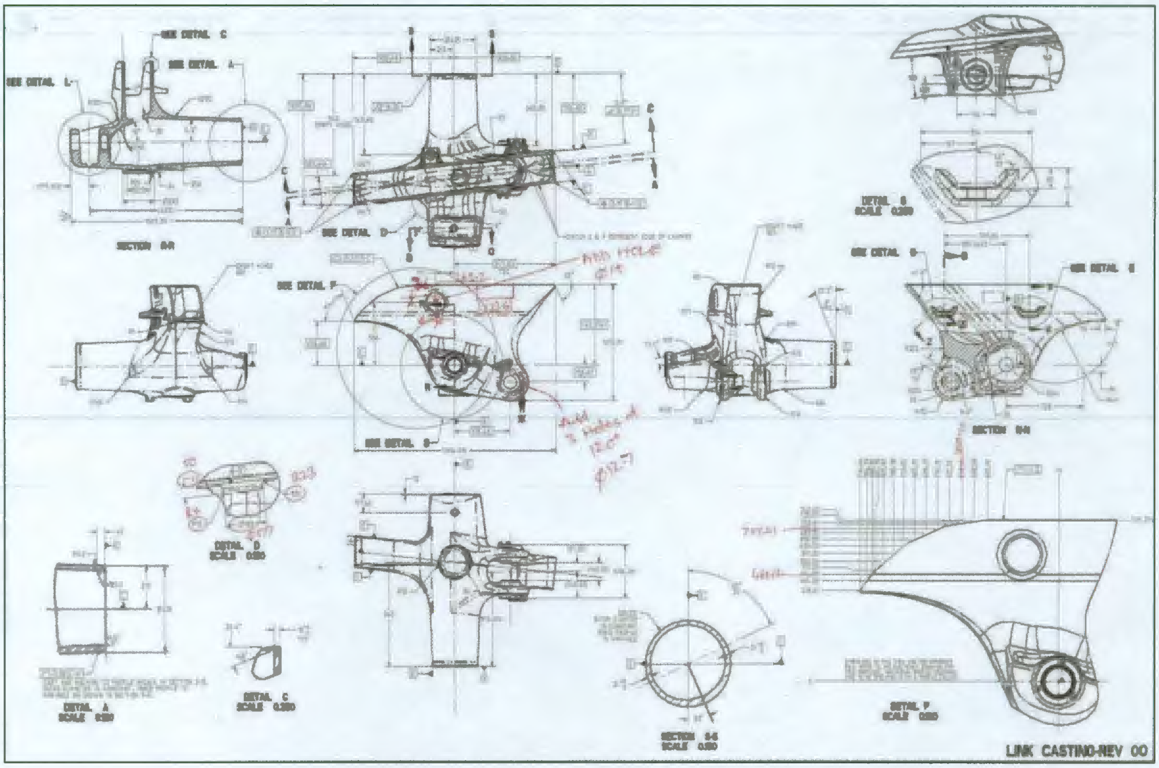


Figure 1 (Drawing Revision 00)

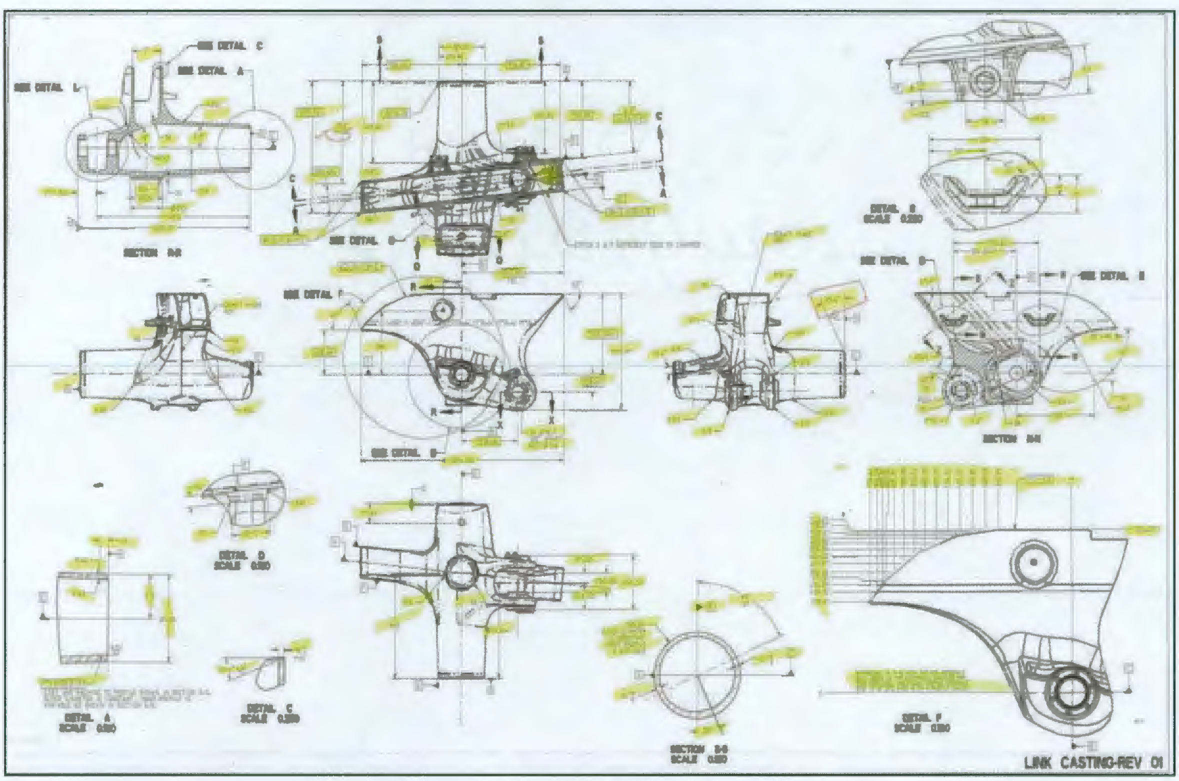


Figure 2 (Drawing Revision 01)

4.6 Data Analysis

Data collected in this research study is used to evaluate whether to implement an efficient drawing checking process or not. Collected data evaluated using P-chart and Pareto chart. The data analysis gives confidence to pick best checking method, with reduction in time and mistakes will be the ultimate drawing checking solution. Since drawing has 330 dimensions, it is considered as a subgroup. The data collection tables, metrics, checklist and statistical calculations are published below.

Manual checking

Manual checking drawing errors are reported in Table 1.

Sample no	Errors	Sample no	Errors	Sample no	Errors	Sample no	Errors
1	1	11	1	21	0	31	0
2	1	12	2	22	3	32	1
3	2	13	2	23	1	33	0
4	2	14	0	24	2	34	2
5	0	15	1	25	1	35	2
6	1	16	1	26	2	36	1
7	2	17	2	27	1	37	0
8	0	18	1	28	1	38	1
9	1	19	2	29	2	39	1
10	1	20	1	30	1	40	0

Table1. Data collection for drawing errors

When the out of control situation is observed in the process, find out which reason behind this out of control situation and try to solve that. Here to measure the amount of data which are out of control limits, P type control chart is used. Since the data is attribute type as shown in Table 2, which means conforming or non-conforming type that's why P chart shown in Figure 3, is mostly suitable here.

$$\bar{P} = \frac{\sum np}{\sum n} = \bar{P} = \frac{46}{13200} = 0.00348$$

$$\text{UCL} = \bar{P} + 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} = 0.00348 + 3\sqrt{\frac{0.00348(1-0.00348)}{330}} = 0.01320$$

$$\text{LCL} = \bar{P} - 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} = -\ 0.00624 = 0$$

Table 2, shows Number of non-conforming pieces from 40 samples with sample size n=330 dimensions.

Sample no	No of abnormalities	Fraction non confirming	Sample no	No of abnormalities	Fraction non confirming
1	1	0.0030	21	0	0.0000
2	1	0.0030	22	3	0.0091
3	2	0.0061	23	1	0.0030
4	2	0.0061	24	2	0.0061
5	0	0.0000	25	1	0.0030
6	1	0.0030	26	2	0.0061
7	2	0.0061	27	1	0.0030
8	0	0.0000	28	1	0.0030
9	1	0.0030	29	2	0.0061
10	1	0.0030	30	1	0.0030
11	1	0.0030	31	0	0.0000
12	2	0.0061	32	1	0.0030
13	2	0.0061	33	0	0.0000
14	0	0.0000	34	2	0.0061
15	1	0.0030	35	2	0.0061
16	1	0.0030	36	1	0.0030
17	2	0.0061	37	0	0.0000
18	1	0.0030	38	1	0.0030
19	2	0.0061	39	1	0.0030
20	1	0.0030	40	0	0.0000

Table 2

In Figure 3, we can see the proportion of nonconforming is well below the upper control limit. As per the graph process is not out of control; however we cannot afford to release a drawing with errors, the target must be zero errors. Hence I will recommend improving checking method for the cause of this high value of nonconforming parts.

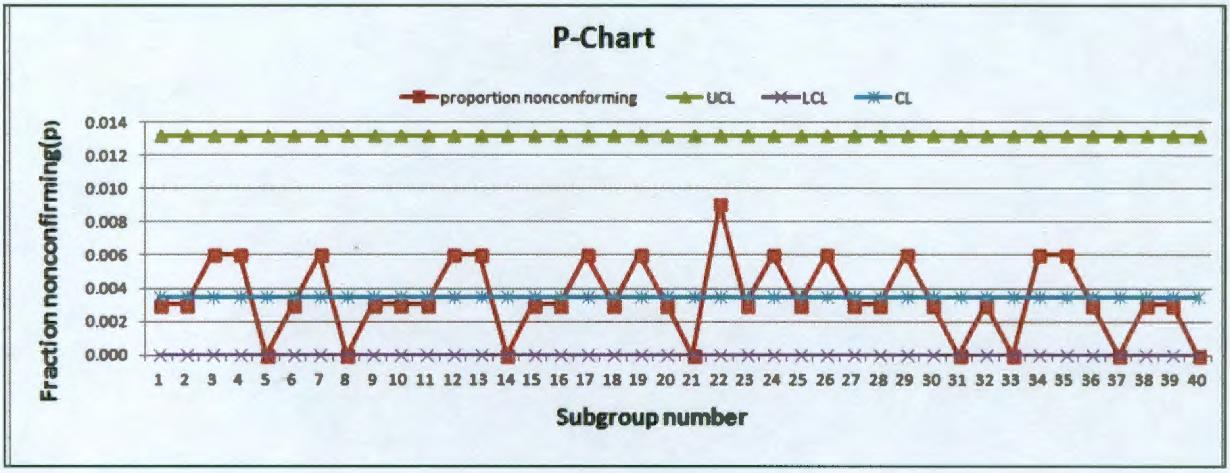


Figure 3

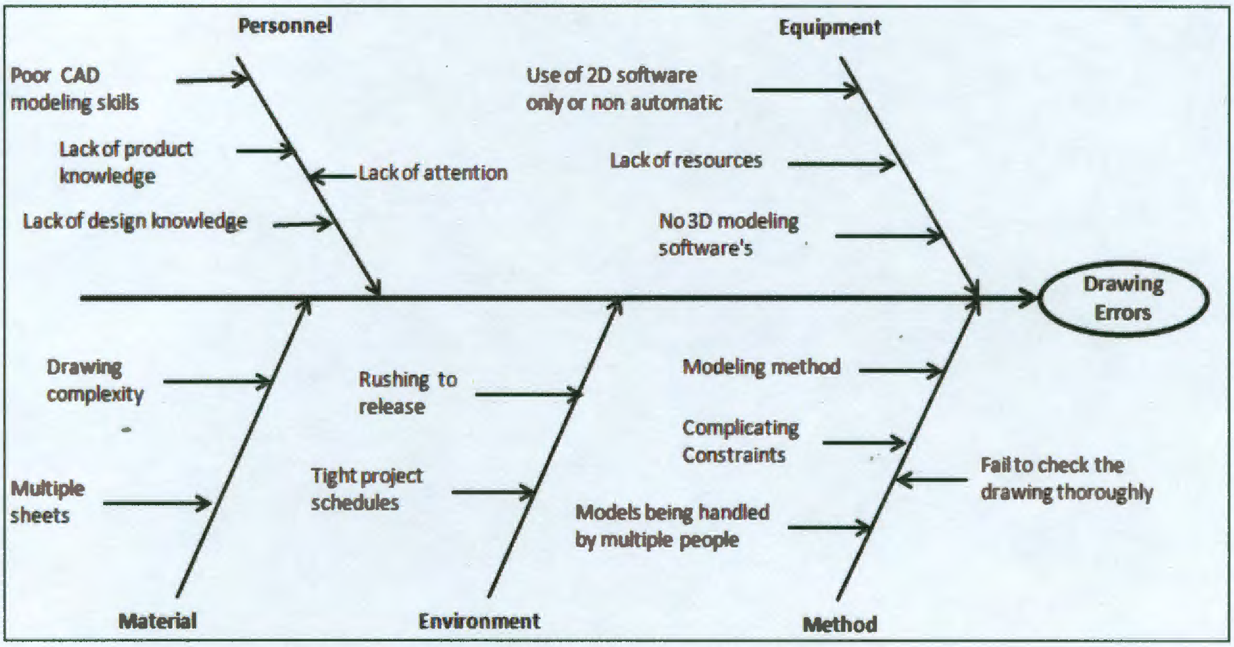


Figure 4. Cause-effect diagram for drawing errors

Creating a cause-effect-diagram to understand the relationship between the CTQs. Cause-effect diagram possible causes for drawing errors have been divided into some major factors by brainstorming data. Then also some specific factors related to those major factors have been identified. Furthermore I have also drawn a Pareto chart to identify the vital few & trivial many. The background reasons were to emphasize on the potential culprits to minimize process variations. All the defect categories are summarized in Table 3 and drawn in Figure 5.

Different types of errors percentage		
Error Type	**No of errors**	**Frequency**
Unintentional changes	28	61%
Intentional changes	6	13%
Newly added dimensions	5	11%
Ignorance	4	9%
Confusion between drawings	3	7%
Total	**46**	**100%**

Table 3

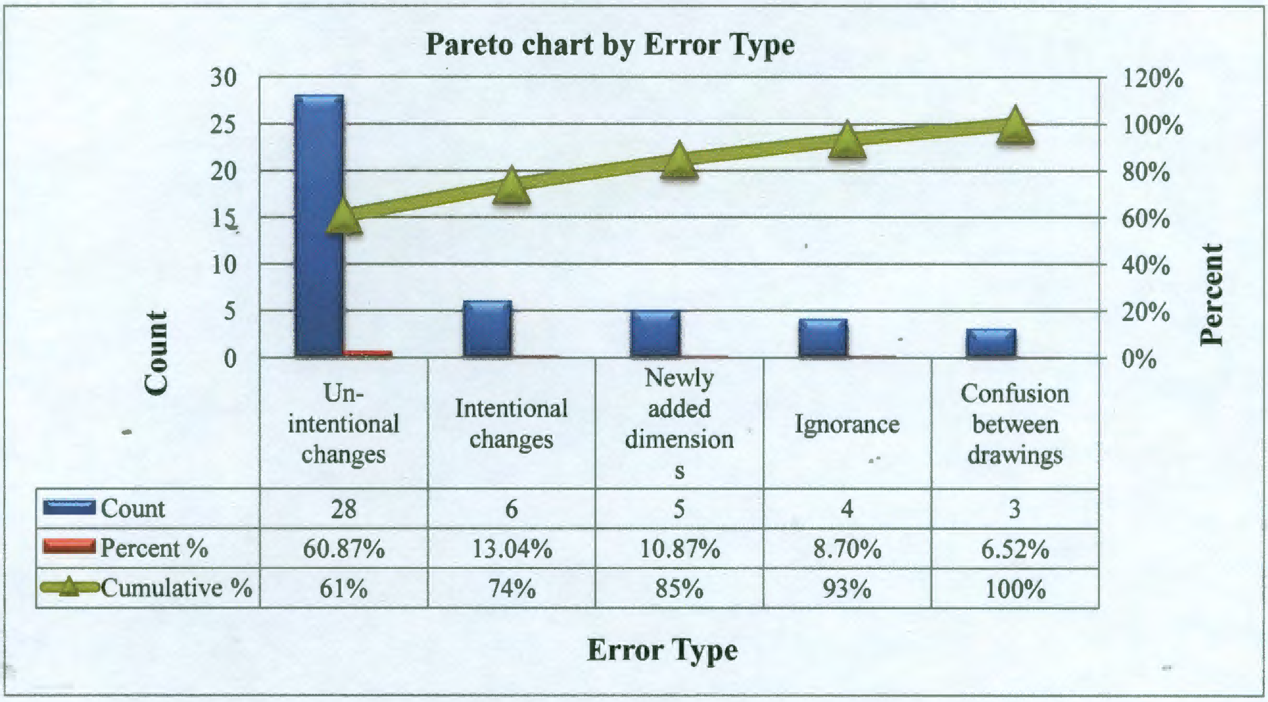


Figure 5 (Pareto Chart)

From the Figure 5 un-intentional changes, intentional changes & newly added dimensions are the vital few which contribute around 85% of total errors.

Customer Requirements (What)		Importance (1-5)	Parametric Modeling	Model Constraining	Automated Dimension	Feature based dimension	Minimize drawing sheets
Direction of Improvement							
Improve	Speed	5	1	3		3	1
	Quality	4	3	3		1	1
	Efficiency	4	1	1		1	1
Reduce	Check time	4	1	1	1		1
	Defects	5	9	3	3		1
	Cost	1		1			
Targets			100%	50%	100%	70%	50%
Absolute Importance			70	51	19	23	22

Design Requirements (How)

High = 9
Medium = 3
Low = 1

Figure 6. QFD model showing the relationship between errors and possible causes for un-intentional changes

In the QFD diagram it is seen that lack of attention on parametric modeling has the highest score. Here in figure 6, the used symbols 1, 3 and 9 represents weak relation, moderate relation and strong relation respectively.

Checking using CAD software

Once drawings are checked manually, subjects are provided with necessary CAD drawing files to check the drawings using CreoView drawing comparison software. Using the software subjects will have to overlap both Revision 00 and Revision 01 drawings to visualize the differences. The software is capable of highlighting the differences in various colors; these colors can be changed as per user preferences. In this case, software is set to show the modified dimensions (Revision 01) and text in red color; the same dimensions on original drawing (Revision 00) will be shown in green color. See Figure 7 for software compared drawing.

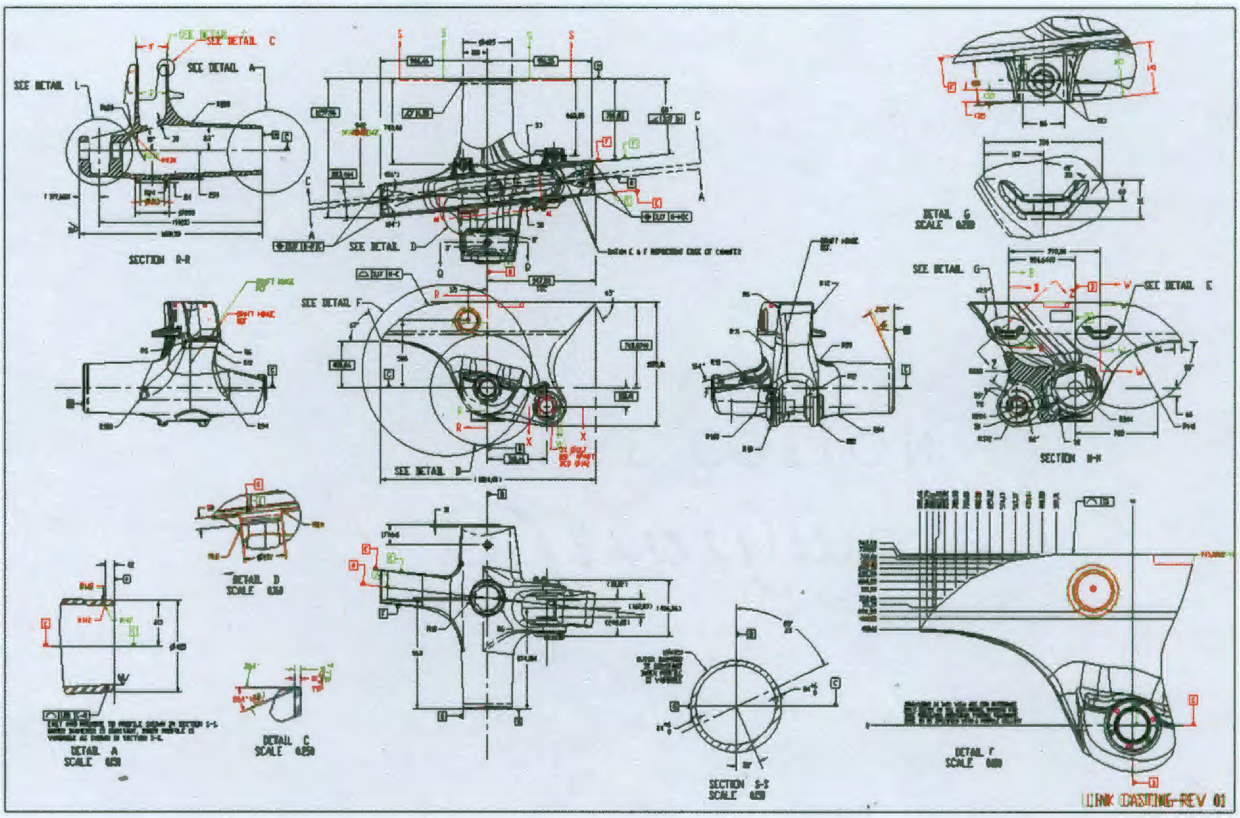


Figure 7

The Figure 7 shows both drawings laid one on top and differences are highlighted in colors and we can tab though next pages at the same time. The subjects recorded the changes and handover a print of drawing with changes marked. All three of drawings sheets will are shown in

Appendix B. Below is the Table 4 for data collected for comparing drawings using CreoView MCAD.

Sample no	Errors	Sample no	Errors	Sample no	Errors	Sample no	Errors
1	0	11	0	21	0	31	0
2	0	12	0	22	0	32	1
3	0	13	0	23	0	33	0
4	0	14	1	24	0	34	1
5	0	15	0	25	0	35	0
6	1	16	0	26	0	36	0
7	0	17	0	27	0	37	0
8	0	18	0	28	0	38	0
9	0	19	0	29	0	39	0
10	0	20	0	30	0	40	0

Table 4

$$\bar{P} = \frac{\sum np}{\sum n} = \bar{P} = \frac{4}{13200} = 0.00030$$

$$\text{UCL} = \bar{P} + 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} = 0.00030 + 3\sqrt{\frac{0.00030(1-0.00030)}{330}} = 0.001318$$

$$\text{LCL} = \bar{P} - 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} = -\ 0.003 = 0$$

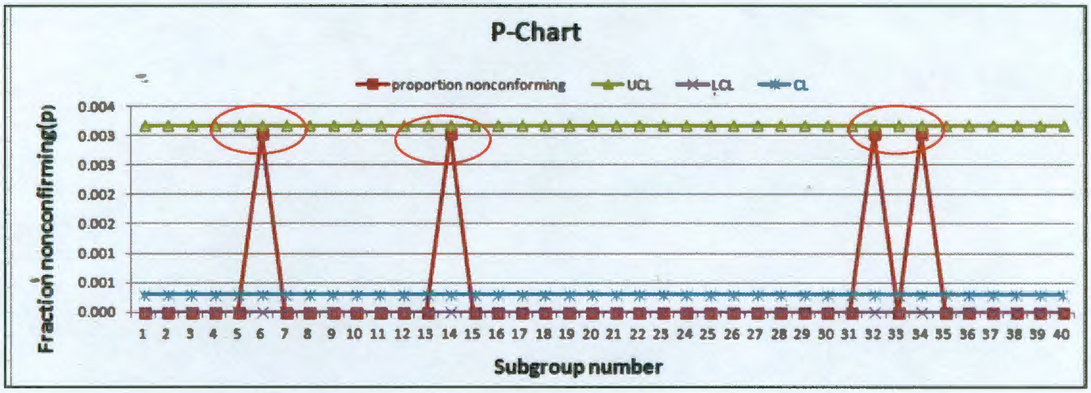


Figure 8

The chart looks good, except 4 points close to the upper control limit and there is no unwanted pattern. We can say confidently that by ignoring points 6, 14, 32 and 34 the process is in statistical control with target of zero errors.

Table 5, shows Number of non-conforming pieces from 40 samples with sample size n=330 dimensions.

Sample no	No of abnormalities	Fraction non confirming	Sample no	No of abnormalities	Fraction non confirming
1	0	0.0000	21	0	0.0000
2	0	0.0000	22	0	0.0000
3	0	0.0000	23	0	0.0000
4	0	0.0000	24	0	0.0000
5	0	0.0000	25	0	0.0000
6	1	0.0030	26	0	0.0000
7	0	0.0000	27	0	0.0000
8	0	0.0000	28	0	0.0000
9	0	0.0000	29	0	0.0000
10	0	0.0000	30	0	0.0000
11	0	0.0000	31	0	0.0000
12	0	0.0000	32	1	0.0030
13	0	0.0000	33	0	0.0000
14	1	0.0030	34	1	0.0030
15	0	0.0000	35	0	0.0000
16	0	0.0000	36	0	0.0000
17	0	0.0000	37	0	0.0000
18	0	0.0000	38	0	0.0000
19	0	0.0000	39	0	0.0000
20	0	0.0000	40	0	0.0000

Table 5

4.7 Summary

This chapter addresses the methods that are used to obtain the data for comparing best drawing checking method. Data collected during test is presented in Table 2 and Table 5. Each drawing associated with large number of dimensions, hence considered each drawing as subgroup. Total number of errors collected from all subjects in manual checking are 46, with an average check time of 21 minutes, while automated checking reported only 4 errors with an average check time is about 5 minutes. The error difference is evident that automated checking is much more effective, accurate and quicker, and will trace un-intentional changes. As data shows there is a clear and significant difference in error rate, so need not to conduct normality test to compare means.

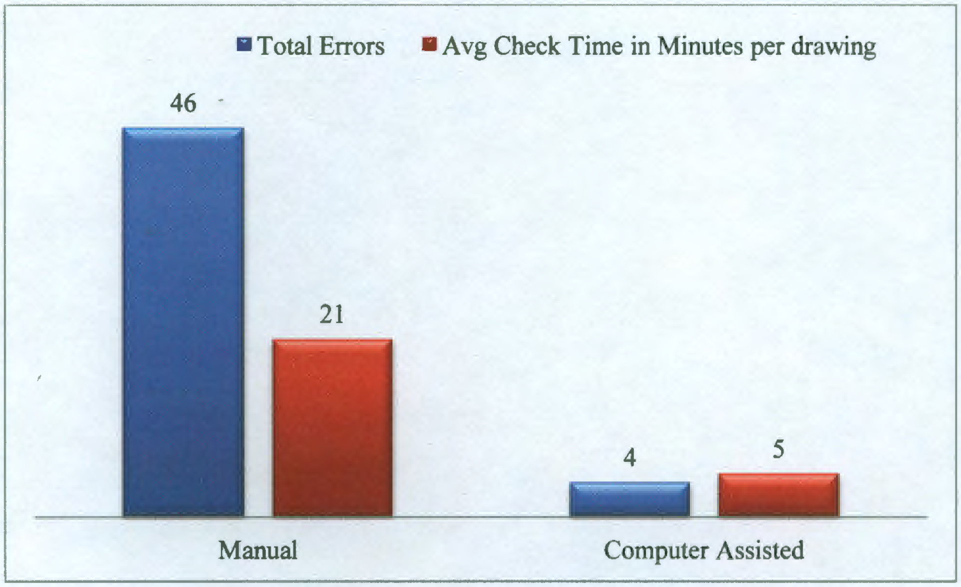


Figure 9 (Drawing errors by method and Average time taken per drawing)

5 Conclusion

The drawing checking process is a continuous and daily activity for engineers. To achieve the best production results for any manufacturing firm is a laborious & time consuming task, and it is possible only if parts are designed right. In this study, I just emphasized on only the comparing drawing checking by manual and automated. The checking of drawings with CAD software can be applied easily in any kind of design and manufacturing areas like service, production, architecture, and civil construction etc. The major outcome of this research is, tracing un-intentional changes, reduce cost, reduce time, maximize engineering resource efficiency, quality of the products and increase customer satisfaction. The subjects reported an average time taken to check drawing manually is 21 minutes, where as automated checking took about 5 minutes. The reduction in time taken to check is about 75%. It is assured that successful implementation of automated checking process will bring huge positive impacts to the organization. Key contributors for un-intentional changes are CAD modeling techniques and no through drawing checking. Current research strongly recommends automated drawing checking using CAD software is most effective and time saving.

6 Recommendations and Future Works

The key objective of this study was to enhance or implement best drawing checking process with a goal of minimizing drawing errors and speed up the check process. In this study, various tools such as Pareto analysis, cause-effect diagram, control chart and QFD have been used. Data have been taken over couple weeks, due to subject's availability and limited CAD software licenses and the test was conducted with four subjects at time. For precise results, more data needs to be collected. Here only one drawing and its causes have been described, and the drawing had total of 330 dimensions. Only p chart has been used to measure the problem, other types like u, c, np etc also can be applied and use of more than one would give more precise results. The subjects reported significantly less time taken to check with use of CAD software; however the time taken for large drawing could be even greater and smaller drawings may not have much impact, but this needs to be confirmed. In this study we can use non parametric drawings such as, Electrical schematics and Hydraulic schematics. The cost of software is not taken into account, because the purpose of this study is to demonstrate the merits of automated checking. There are several software packages available in the market that serves the same purpose. Following are the name of the software.

- PTC CreoView MCAD
- Team center
- Autodesk

7 References

[1] Fraenkel, J. R., & Wallen, N. E. (2006). How to design and evaluate research in education. Boston: McGraw-Hill.

[2] VASKÝ, J., & GRAMBLIČKA, M. (2014, December). Experimental Evaluation of Integral Transformations for Engineering Drawings Vectorization. 1-8.

[3] Mirković, S., & Budak, I. (2015). Application of modern computer-aided technologies in the production of individual bone graft: A case report. 1126-1131.

[4] Hirz, M., & Harrich, A. (2009, November 5). Advanced 3D-CAD Design Methods in Education and Research. 30-34.

[5] Vinicuis, M., & Martins, M. (2014, August 15). Computer-aided design of a coffee-dragging device.

[6] Bodein, Y., Rose, B., Caillaud, E., 2014, "Explicit Reference Modeling Methodology in Parametric CAD System" Computers in Industry 65(1), pp. 136-147

[7] Leahy, K. 2013. Promoting best practice design intent in 3D CAD for engineers through a task analysis. American Journal of Engineering Research 2(5) pp. 71-77.

[8] Jami J. Shah., 2001. Designing with Parametric CAD: Classification and comparison of construction techniques, pp. 53-68.

[9] Wang, Y., Nnaji, B.O., 2005. Geometry-Based Semantic ID for Persistent and Interoperable Reference in Feature-Based Parametric Modeling. Computer-Aided Design 37(10), pp. 1081-1093.

[10] Hillyard, R. C., and Braid, I. C., 1978, Analysis of dimensions and tolerances in computer aided mechanical design, Computer-Aided Design 10(3):161-166.

[11] Light, R. and Gossard, D., 1982, "Modification of geometric models through variational geometry", Computer-Aided Design, Vol. 14, No.4, pp. 209-214

8 Appendix

8.1 Appendix A

Drawing checklist required for manual drawing checking, this checklist can be customized per requirements.

Drawing Checklist **Drawing Number:** ______________

- ☐ Is title block latest/ appropriate?
- ☐ Is the title clear and meets standards.
- ☐ Are the sheet numbers in sequence?
- ☐ Is the date updated?
- ☐ Have you pulled correct drawing and models Revisions?
- ☐ Are the notes present in first sheet?
- ☐ Does BOM quantity matches to model quantities?
- ☐ Are the BOM numbers matching with balloons?
- ☐ Did you confirm drawing and models in workspace are latest?
- ☐ Did you print correct revisions of drawings for comparison or checking?
- ☐ Did you check if all the markup changes are done?
- ☐ Have you checked all dimensions and details to make sure unwanted changes took place
- ☐ Are the drawings compared using Creo View MCAD?
- ☐ Are the drawings files latest as per their revision
- ☐ Did you compare all the sheets
- ☐ Have you checked newly added views and shifted views from their location.

8.2 Appendix B

LINK CASTING REV-00, page 1 shows the markups for changes to be done. Due to image size and over all file size I am attaching only one page of this drawing for reference.

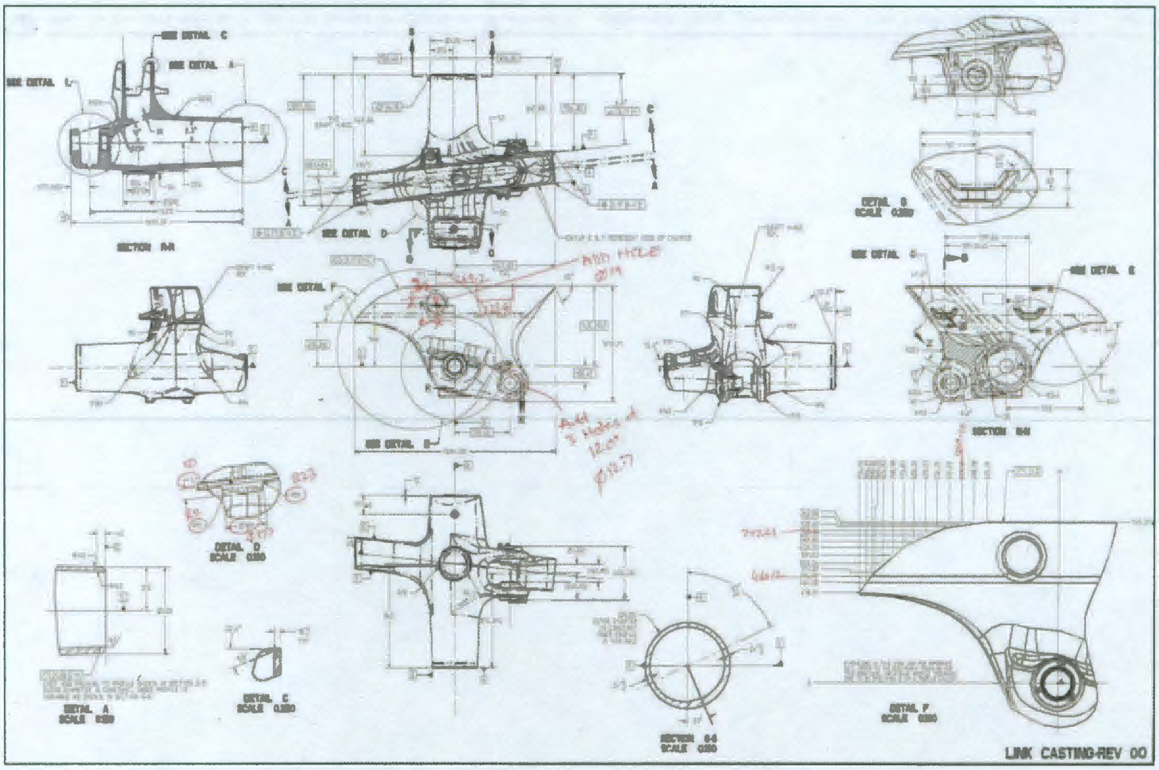


Figure 1 (Drawing Revision 00)

LINK CASTING REV-01, a sample checked drawing attached for reference. Due to image size and over all file size, I am attaching only one page of this drawing for reference. One of the dimension circled in red was modified un-intentionally was not traced in manual check.

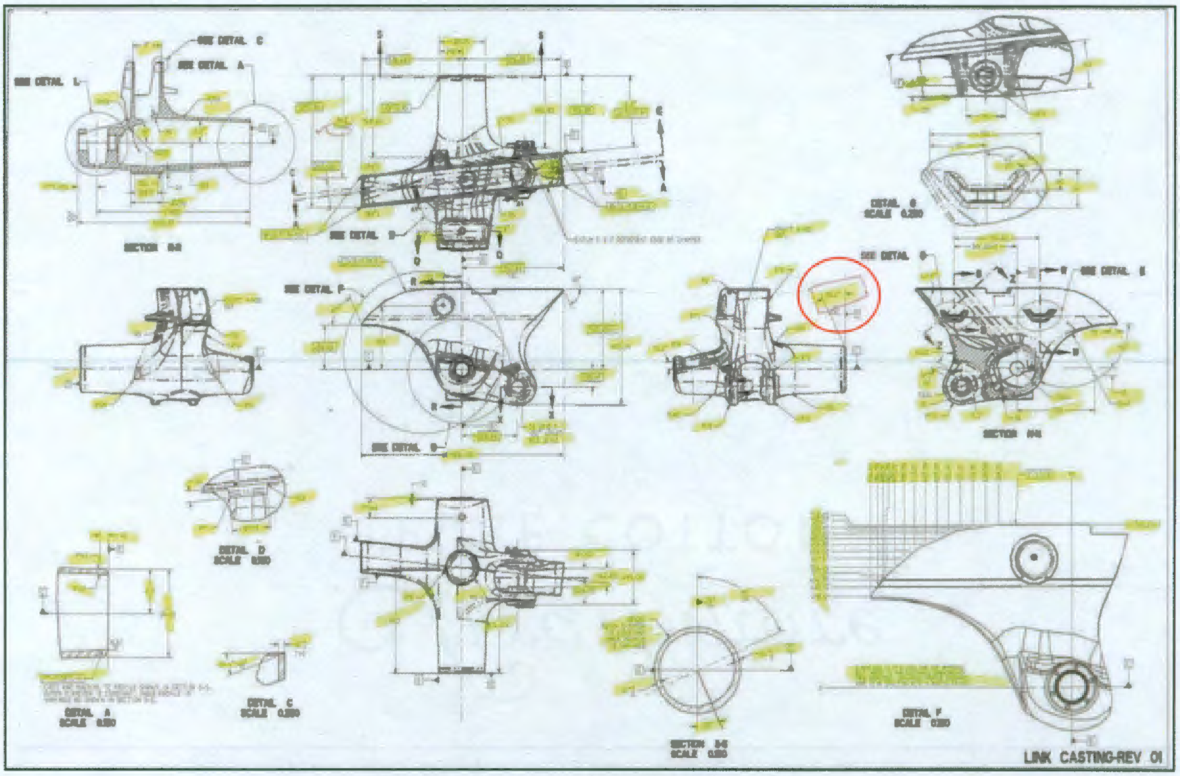
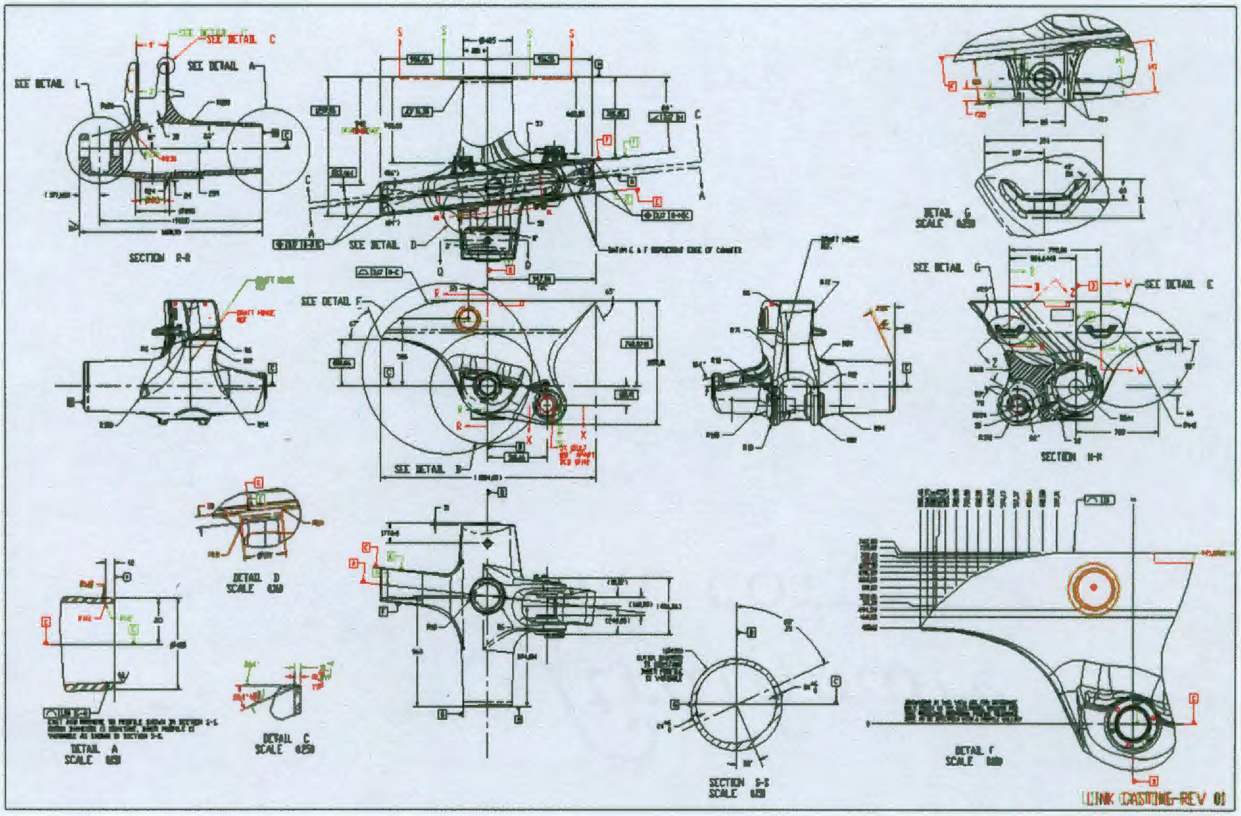
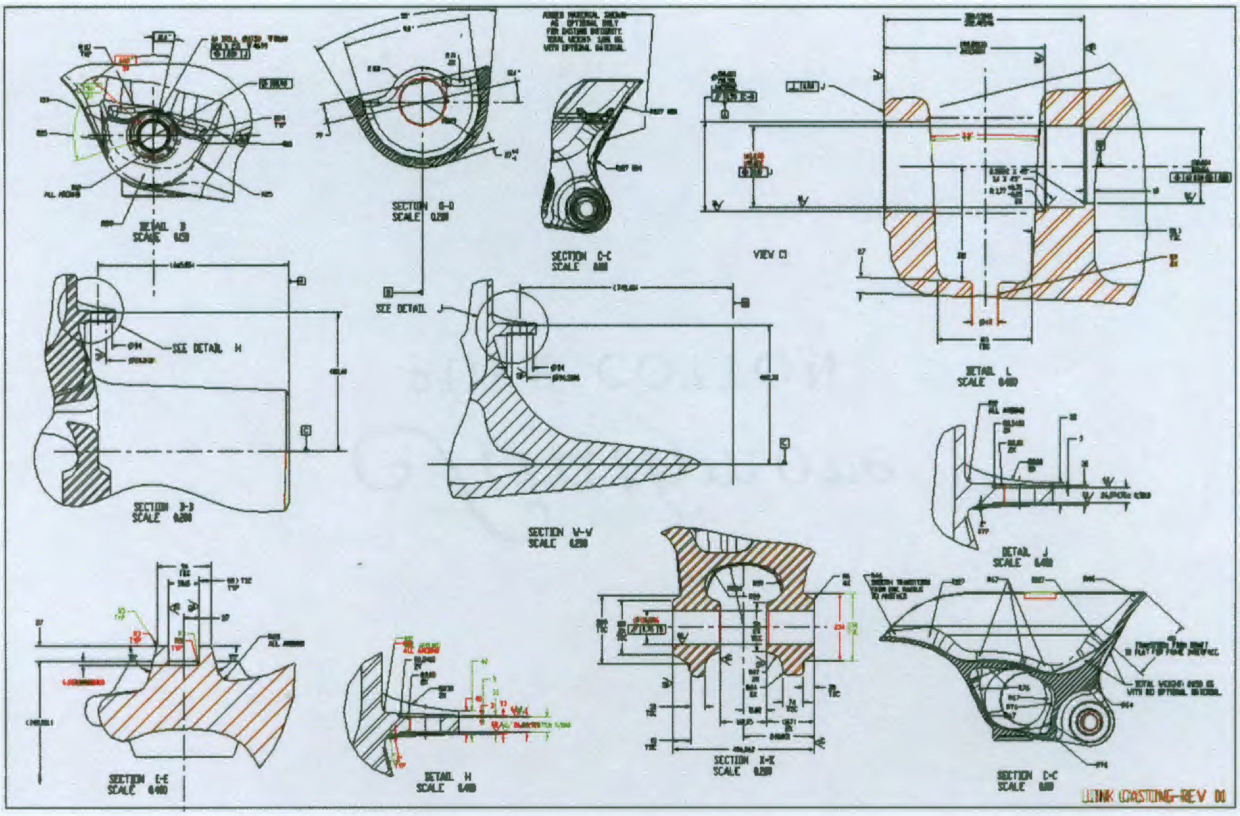


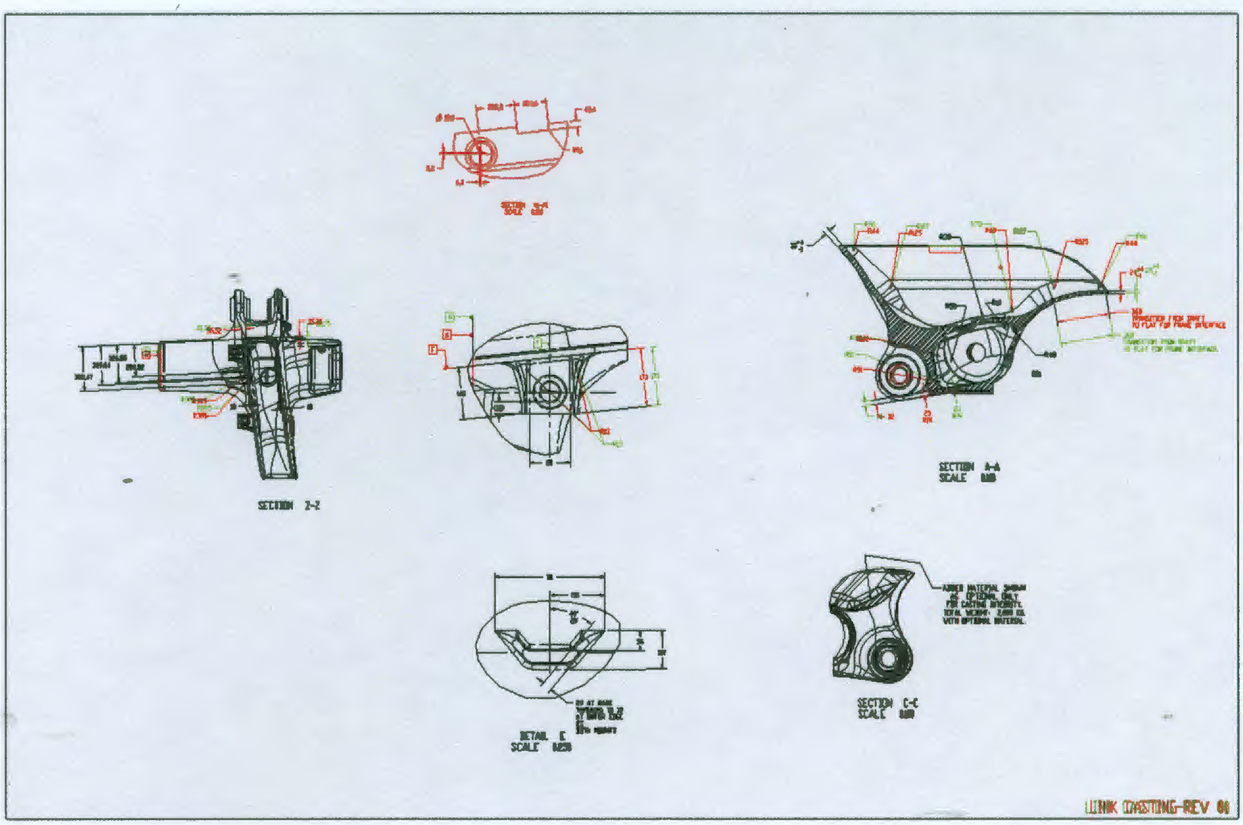
Figure 2 (Drawing Revision 01)

8.3 Appendix C

Automated checking overlapped LINK CASTING REV-00 (In green), LINK CASTING REV-01 (In red) drawings are shown below.




SEE DETAIL H
SEE DETAIL J
VIEW C1
SECTION C-C
SECTION V-V
SECTION X-X
LINK CASTING-REV 00


SECTION Z-Z
SECTION A-A
SECTION C-C
LINK CASTING-REV 00