Boeing X-Ray Inspection Process Improvement

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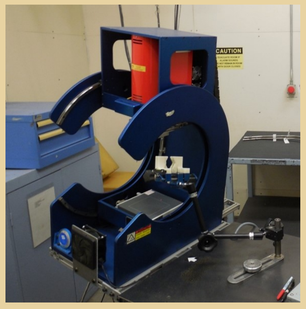
BOEING

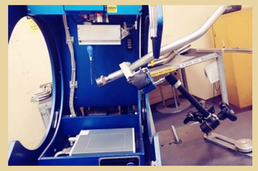
Introduction

Problem Statement
Currently, 55% of process time for the X-ray inspection is being used to align and orient tubes for imaging.

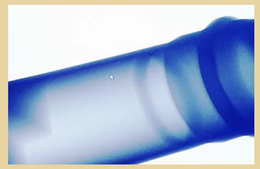
Goal Statement
Our goal is to improve the overall X-ray inspection process and increase throughput of the cell



X-Ray Machine



Current Fixture



X-Ray Image

Initial Observations

Number of Samples

$$N = \frac{1.96 \ * 47.0733}{0.05 * 282.475} = 43 \ samples$$

The numbers used for this calculation were from an initial round of time studies using 8 samples.

Time Study Data

Element Number	Element Description	Average Time (Seconds)	Standard Deviation (seconds)	Percentange (std/avg)
1	Grab part from incoming shelf and office time/paperwork	69.49	25.10	0.36
2	Get part	13.06	11.30	0.86
3	Orient X-ray	9.08	4.18	0.46
4	Clamp the tube	10.60	4.31	0.41
5	Align the tube	9.67	4.17	0.43
6	Close door	17.40	5.18	0.30
7	Start X-ray	15.25	6.02	0.39
8	Align the part	14.47	7.33	0.51
9	Imaging	18.60	9.20	0.49
10	Enter name	7.75	2.23	0.29
11	Orient to another direction	11.85	3.17	0.27
12	Imaging	11.25	3.62	0.32
13	Enter name	7.15	1.68	0.24
14	Open the door	11.05	3.37	0.30
15	Remove the tube	9.70	3.87	0.40
16	Repack the tube	11.83	6.26	0.53
17	Put tubes on the shelf	13.30	8.82	0.66
Total cycle time:		261.49		

Based on our 22 time study samples, we found that the average cycle time was 261.49 seconds.

Internal vs. External Steps

INTERNAL	EXTERNAL
Start X-ray	Grab part from incoming
Align the part	Get part
Enter name	Orient X-ray
Orient to another direction	Clamp the tube
Enter name	Align the tube
Open the door	Close the door
	Remove the tube
	Repack the tube
	Put tubes on shelf

Process steps were broken down into internal and external steps to determine places for improvement

Impact of Batching

Using 2 Fixtures

$$261.49 \ \frac{sec}{unit} = \frac{(setup \ time) + (175.2 * 2)}{2}$$

Setup time = 172.4 sec ~ 3 minutes

Using 3 Fixtures

$$261.49 \ \frac{sec}{unit} = \frac{(setup \ time) + (175.2 * 3)}{3}$$

Setup time = 258.87 sec ~ 4 minutes

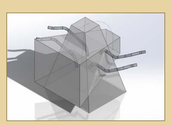
FMEA

Types of Failure

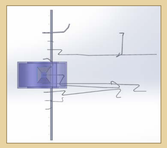
Mechanical | Process | Operator

Type of Failure	Process Step/Input	Potential Failure Mode	Potential Failure Effect	Potential Cause	Action Taken
Mechanical	Clamping mechanism	Clamp could damage tube	Delay in parts/ delivery	Clamp is too strong and damage tube	FEA testing and quick clamp
Process	New setup process with new fixture	Not able to get images that meets requirements	Parts sent back if defect found later	Tubes not in correct orientation	Impact of batching, system for tube alignment
Operator	Positioning new fixture	Not ergonomical	Operator will not like it	Clamp my require more hand strength	Adjust position and tension of clamp

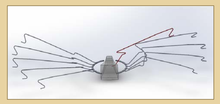
Preliminary Approach



1. Static



2. Sliding



3. Individually Actuated

Design Matrix		Alternatives		
Criteria	Weight	1.Static	2.Sliding	3.Individually Actuated
Batch Size	2	1	3	3
Usability / learning curve	2	3	2	1
Lifetime	1	3	2	1
Ability to capture all tubes	2	2	2	3
Set up time per part	3	2	2	2
Cost	2	3	2	1
Processing time /part	3	3	2	2
Total		36	32	29

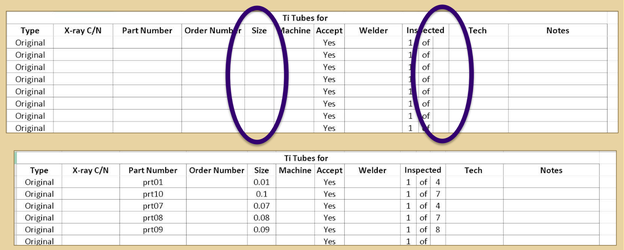
Goal: Reduce process time
Weight:
0 to 3 (where 0 stands for 'not important' and 3 for 'very important')
Degree of satisfaction:
0 to 3 (where 0 stands for 'not at all' and 3 for 'excellent')

In our ideation phase we explored ways to batch and decrease per-part setup time (3 alternatives above) We chose to design the static fixture. This was mainly based on the decision matrix shown below and that the 2nd and 3rd alternatives heavily rely on automation which fails easily in irregular conditions such as inspection and is expensive for a non-value-added process.

Material Handling

- Foam to keep parts from hitting each other
- Decrease transportation time
- Eliminate need to unload units from incoming to X-ray room table

Excel Automation Macro



Ti Tubes for

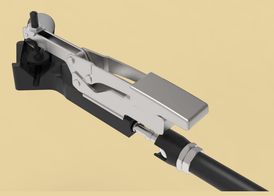
Type	X-ray C/N	Part Number	Order Number	Size	Machine	Accept	Welder	Inspected	Tech	Notes
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		
Original						Yes		1 of		

Ti Tubes for

Type	X-ray C/N	Part Number	Order Number	Size	Machine	Accept	Welder	Inspected	Tech	Notes
Original		prt01		0.01		Yes		1 of 4		
Original		prt10		0.1		Yes		1 of 7		
Original		prt07		0.07		Yes		1 of 4		
Original		prt08		0.08		Yes		1 of 7		
Original		prt09		0.09		Yes		1 of 8		
Original						Yes		1 of		

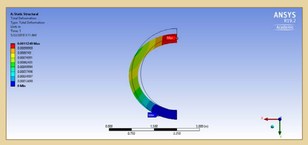
Initial observations and time study results: operators spent a lot of time entering information about parts. The excel sheet had two fields that had the potential to be automated. Using a VLOOKUP table, we reduced the per-row workload from 3 scanned cells, 2 manual cells and three drop down cells to just three scanned and three dropdown.

Clamp Fixture



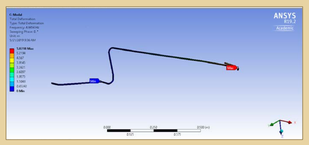
Quick clamps fixture with two grooves provides more freedom for orienting tubes for X-ray imaging. Inefficient movements for setup could be avoided.

FEA Testing



- Test case: Largest tube OD, smallest wall thickness, weakest material
- STC-HH50 Max Clamping Force: 250 lbf
- Max Internal Stress: 2892 psi
- Yield Strength of Al 6061: 40,000 psi

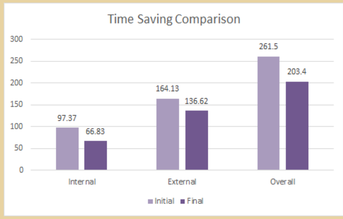
Vibrations Testing



- Natural frequency of 4.6 Hertz
- Overdamped vibration likely to propagate in the inspecting region.
- Need support for tail of long tubes. This justifies the current support used in the inspection room to hold the tail of long tubes.

Overall Results

Process Time Comparison



Final time study data with new fixture only had 6 samples however, it gives a rough estimate of the time saved. Based on the data collected, the is an estimated 22% time savings however, we predict around 15% time savings based on variability of tubes and limitations of the time study samples.

Ergonomics: Cart will reduce the time the operator spends moving parts to and from the X-Ray room. It will reduce the need to lift heaving parts. The quick clamp will also reduce the strain on the operators hand by eliminating twisting motion

Impact on Boeing TDRC
- Ability to have multi-piece processing without capturing image obstruction during the x-ray inspection
- User-friendly design could reduce the training time on new employees

Soft Benefits
- Improving the process time at this bottleneck will increase the throughput at this cell and hopefully the whole facility

Cost Savings Analysis

Assumptions: Boeing Employee Labor Grade (Level 5)
Minimum pay rate: $16.00
Maximum pay rate: $39.61
1st Shift: 6am-3pm
2nd Shift: 3pm-12am
Total working hours per week (not including breaks/lunch)
16hr/day*5 = 80 hr/week
Weeks worked per year: 48 weeks

Minimum cost savings/year estimate (min pay rate): $13,653
Maximum cost savings/year estimate (max pay rate): $31,240

Future Recommendations

Double Sided Clamp
We would recommend exploring the option of a double sided clamp to reduce the setup time be reducing the difficulty of orienting the tubes.

Boeing Integration
Taking these new tools and procedures into the future at Boeing may be a challenge but since there are many new employees in the cell still in training, we have a unique opportunity. We can build SOP's that effectively address the changes we made and allow us to touch on other small areas to improve the process.

Acknowledgements

A huge thank you to the following people: Patty Buchanan, David Flores, Tyler Watada, Boeing X-ray Inspection team, and Kellus Stone. This project would not be possible without your support. Thank you!