CIS-Carbon Footprint Evaluation and Improvement in Production Line Project Report

WPI/HUST Project - Wuhan, China

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Abstract

The problem of “Global Warming” is receiving considerable attention nowadays with the concentration on the biggest producers of CO2; the United States, Europe, and China. Focusing on a manufacturing plant in china named Central Industrial Supply. The analysis of emissions and the theoretical modeling of how to reduce the emissions was the goal of this project. Evaluating the Carbon footprint of the company using equations found from reputable environmental articles. An evaluated 8301g of CO2 per product was found, this number includes emissions from transportation, raw material, parts producing, packaging, and environment. The second part of the project was to Create many different ways to reduce each parts Carbon footprint, a theoretical reduction of 3.6% per product was calculated. Now that number appears small, however because the company makes 291 products an hour and works 7 hours a day for 260 days a year this little 3.6% becomes a reduction of about 22,698 kg of CO2 a year.

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1.Introduction

What’s carbon footprint (CFP)?

The area of carbon footprint has attracted significant attention in the last twenty years. A carbon footprint is defined as: The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO2).[i]

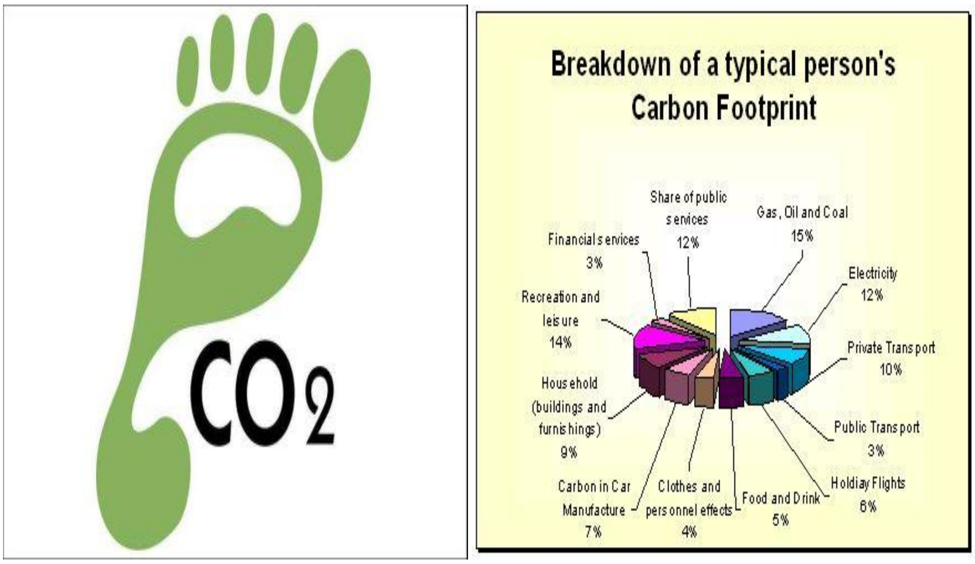


Figure 1: carbon footprint

About CIS

Asia Pacific CIS Wuxi, the headquarters of which are in Phoenix AZ, offers complete product development that’s a world apart. Specializing in contract manufacturing of electromechanical components and assemblies for OEMs (original equipment manufacturers), CIS provides components and services that improve your competitive advantage and enable rapid response to market changes.

Figure 2 : CIS products

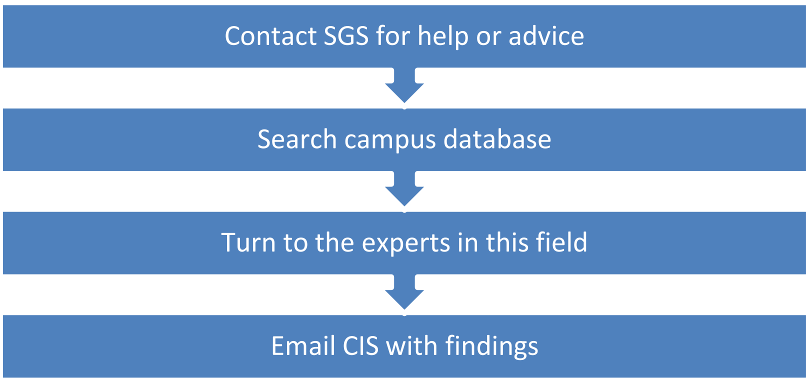
Problem statement

The aim of the project is to analyze the production line of CIS and to calculate the CFP of the product line for DELL 2U. Then with the information gathered, to formulate recommendations on how to improve the production line and reduce the CFP.

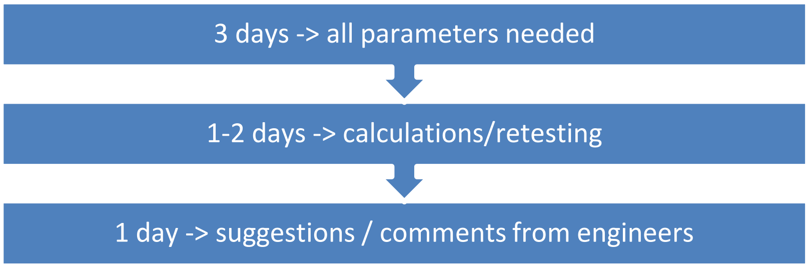
Arrangement and schedule

Preliminary arrangement

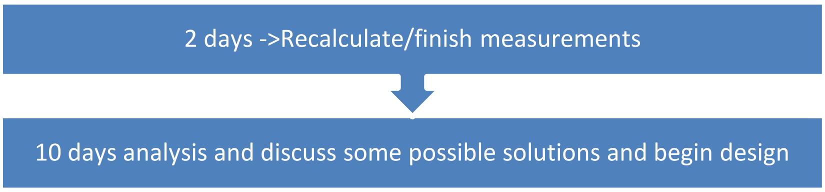
* Measuring: June 30 -> July 9



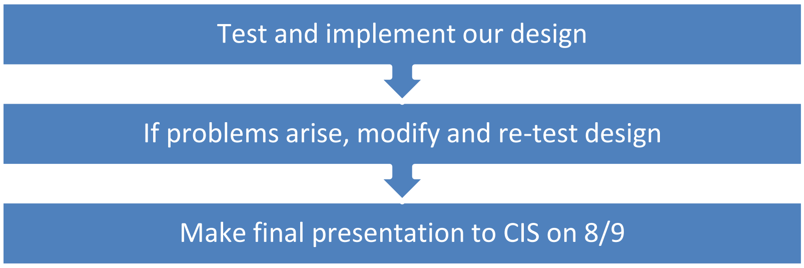
* AT CIS measuring: July 11 – July 15



* HUST: July 16 -> August 1



* On-site @ CIS: August 1 -> August 9



* HUST: August 10 -> August 12

1-2 days to prepare for final presentation

Project Schedule

ID	Tasks	Beginning Time	Finished Time	Duration	2011年 07月 7/3 7/10 7/17 7/24 · 2011年 08月 7/31 8/7 8/14
1	Literature Study at HUST	2011/6/30	2011/7/8	7d	
2	Measure production line at CIS	2011/7/11	2011/7/15	5d	
3	Analyse and find out solutions at HUST	2011/7/18	2011/7/29	10d	
4	Test and modify solutions at CIS	2011/8/1	2011/8/9	7d	
5	Prepare final presentation at HUST	2011/8/10	2011/8/12	3d	

Figure 3: schedule for the project

2. Background Research

To better comprehend our objective, we must first have a strong understanding of what a carbon footprint really is. A carbon footprint in layman's terms include, but is not limited to, carbon dioxide (CO^2) emissions related to any corporation, building, etc. As defined by brittannica.com, a carbon footprint includes direct emissions, such as those that result from fossil-fuel combustion in manufacturing, heating, and transportation, as well as emissions required to produce the electricity associated with goods and services consumed. In addition, the carbon footprint concept also often includes the emissions of other greenhouse gases, such as methane, nitrous oxide, or chlorofluorocarbons (CFCs). When displaying the amount of CO^2, the most common unit of measure is the metric ton per year.

The amount of CO^2 measured can be depicted in several different ways. The two main

List of countries by 2007 emissions [edit]

Rank	Country	Annual CO2 emissions[8][9] (in thousands of metric tonnes)	Percentage of global total
	World	29,321,302	100%
1	China[10]	6,538,367.00	22.30%
2	United States	5,838,381.00	19.91%
-	European Union (27)	4,177,817.86[11]	14.04%
3	India	1,612,362.00	5.50%
4	Russia	1,537,357.00	5.24%
5	Japan	1,254,543.00	4.28%
6	Germany	787,936.00	2.69%
7	Canada	557,340.00	1.90%
8	United Kingdom	539,617.00	1.84%
9	South Korea	503,321.00	1.72%
10	Iran	495,987.00	1.69%

representations of a carbon footprint are total weight and per capita. As seen below, China produces the most total emissions as of 2007, mainly due to its large industrial scene. The United States is second to China by only about 2.5%. Per capita however, China is one of the best countries this is due to its large population. If you take away all the carbon neutral farmers in China you can see the true number which is very close to the United States.

http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions

Figure 4 List of countries by 2007 emissions

To decrease the total amount of CO^2 emissions, our group will have to come up with strategies called carbon offsets. A carbon offset is anything that provides a reduction in CO^2 emission within the carbon footprint.

3. Objectives Statement

A products carbon footprint measures the greenhouse gas emissions at each stage of the product's life. This includes:

- Extraction, production and transportation of raw materials
- Manufacture or service provision
- Distribution
- End-use
- Disposal/recycling

At each stage greenhouse gas emissions can result from such sources as: energy use, transportation fuel, refrigerant losses from air conditioning units and waste. In the case of a "service product" the life-cycle stages are defined across the duration of the service. [ii]

The objective of this project is to develop a methodology for evaluating DELL-2U's CFP and illustrate it with sample data collected and gathered for this purpose. Then, formulate recommendations on how to improve the production line and reduce the CFP.

Specific objectives are listed below:

- Create concrete formula to measure the production lines and gather measurements
- Identify the weakest link in production line
- Design system or device (line level or machine level) that limits carbon emissions.
- Make the effect of our changes sustainable and efficient both economically and environmentally.

4. Methods

Which way to calculate CFP?

Through the literature search, two different ways to calculate CFP were found. Wang Wei and his team suggest the way based on the process[iii], while researchers from Peking University provide another way based on input and output in their document[iv].

Way based on input and output

EIO-LCA model:

- The first level is the direct carbon emissions in the production and transportation.
- The second level makes the boundary of the first level extended to the energy consumption in industrial sector, such as electricity. Specifically referring to the carbon emissions of the full life cycle.

- The third level covers the front two levels, the direct and indirect carbon emissions involved in the production chain.

Calculation Steps:

1. **Calculate the total output**

$$X = (I + A + A*A + A*A*A + \cdots)y = (I - A)^{-1} y$$

Where,

X is the total output,

I is unit matrix,

A is the direct consumption matrix,

y is the final demand,

$A*y$ is the sector's direct output,

$A*A*y$ is the indirect output of sector.

2. **Calculate carbon footprint at the different levels**

- First level: $b_i = R_i(I)y = R_i y$
- Second level: $b_i = R_i(I + A^{'})y$
- Third level: $b_i = R_i X = R_i(I - A)^{-1} y$

Where,

b_i is the carbon footprint,

R_i is matrix for CO_2 emissions,

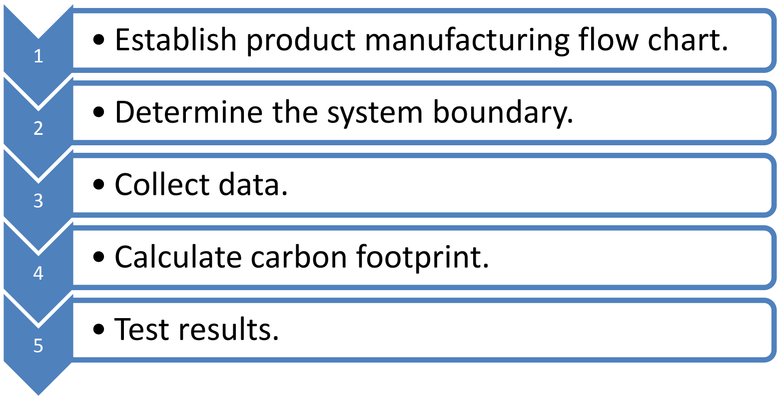
$A^{'}$ is the direct consumption of energy sector.

Limitation:

- The method is to calculate the CO_2 emissions sector, but there are many different products. The average processing method is prone to error.
- The input-output analysis method can only get industry data, the product data is not known. So it can only be used to evaluate a particular sector or industry's carbon footprint, it cannot calculate the carbon footprint of a single product.

Way based on process

Calculation Steps:



Formula:

$$E = \sum_{i=1} Q_i \times C_i$$

Where E is the product's carbon footprint.

Q_i is the number or intensity data (mass/volume/KM/Kwh)of substance or activity.

C_i is the unit of carbon emission factor(CO_2 eq/unit).

Scope of application:

Different scale for carbon footprint accounting, such as production/ individual/ family/ organization/ city/ region/ country, etc.

Limitation:

- Since this method allows use the second data when the original data cannot be informed, and therefore may affect the credibility of result.
- Carbon foot print analysis doesn't put deep thought on the raw materials and product supply chain in the non-important part.
- Since we cannot get the carbon emissions of product in each retail process, so the carbon emissions or retail phase can only be averaged.

The way we choose

The way was chosen based on process for the following reasons:

- The input-output analysis can only get industry data, (not product data) so it can calculate CFP of a sector but not one particular product.
- The method uses the average value to evaluate one product, there must be error.

Calculation Steps

Establish product manufacturing flow chart

First, a product manufacturing flow chart and determine the system boundary is created.

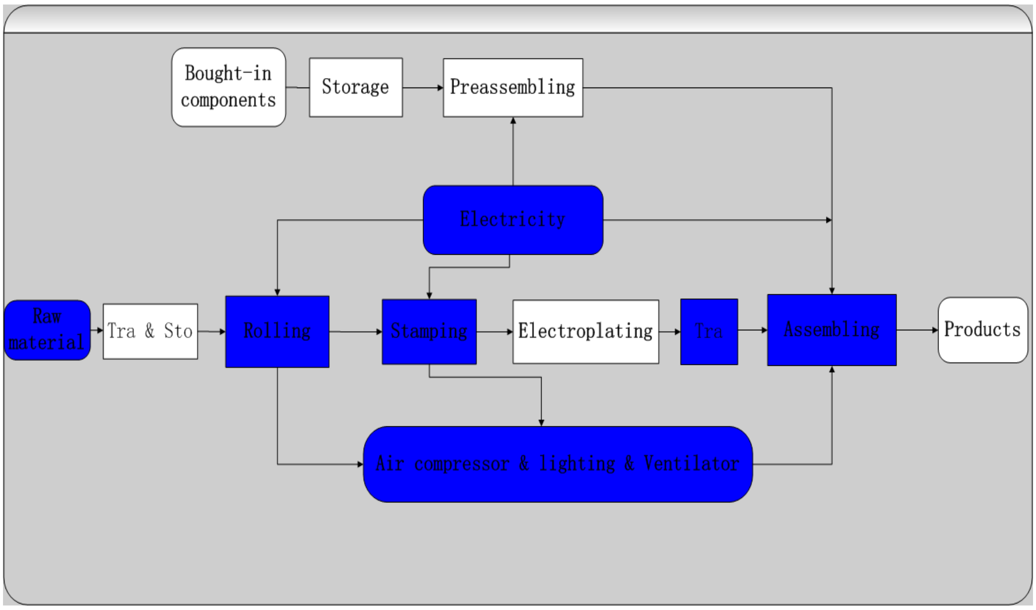


Figure 5: product manufacturing flow

The above figure is the product manufacturing flow chart, and the colored parts are what were focused on. (Raw material, rolling & stamping, electricity, transportation, assembling, and environmental consumption, etc.)

Determine specific way to calculate CFP

Next, determine the specific way to calculate CFP of every step focused on.

Take the CFP in transportation for example:

- Get the carbon emission factor of gas and other fuel.
- Get the average fuel consumption of the truck (L per 100km) (different trucks.)
- Get the loading situation of the trucks (weight on load, empty back or not, fuel consumption in loading and unloading).
- Measure the distance of transportation (consider difference in storehouses).
- Consider possible wrong way case and make compensation in distance measurement.

Data collection

Data about electricity

Considering electricity plays a vital role in the calculation of CFP, much focus was put on the carbon dioxide emission factors for electricity.

Coal plays a dynamic role in electricity generation worldwide. In China coal fuels a high percentage of electricity. Simply, it's believed that the power used in CIS is thermal power and generated from coal.

Many kinds of coal are used to generate electricity, and each of them has advantages and disadvantages.

Coal power plant classification:

Anthracite: Vdaf ≤ 10%, high heat and carbon content, difficult to ignite;

Lean coal: Vdaf = 10 ~ 20%, lots of ash;

Bituminous coal: Vdaf = 10 ~ 50%, high carbon content, less water, high heat .

Lignite: Vdaf> 40%, high moisture and ash content, low heat, ignite and burn easily.

Coal equivalent

1 kg coal equivalent corresponds to a value specified as 7,000 kilocalories. 1kwh power consumes 327g coal equivalent, of which 99% of the carbon emissions is CO_2 .

Carbon content

The level of carbon content is closely related with the coal deepening rank, with the deepening of coal rank coal carbon content gradually increased. China's various types of coal in order from high to low carbon content[v]:

Table 1: carbon content of different kinds of coal

Type of coal	Carbon content
anthracite	91.93%
lean coal	90.26%
fat coal(bituminous one)	87.55%
Lignite	71.56%

Heat

We get heat range of each coal:[vi]

Table 2: heat of different kinds of coal

Type of coal	heat
anthracite	7277-7602 kcal / kg
lean coal	7508-7905 kcal / kg
fat coal(bituminous one)	7816 kcal / kg
Lignite	5215-6016 kcal / kg

CFP equation

Therefore, the equation calculating CFP of 1kW·h for different kinds of coal:

$$\text{CFP}=\frac{327\times 7000\times \text{carbon content}\times 44\times 99\%}{\text{heat}\times 12}=\frac{8309070\times \text{carbon content}}{\text{heat}}$$

The results for different kinds of coal:

Table 3: CFP of different kinds of coal

Type of coal	CFP
anthracite	1.004-1.049kg
lean coal	0.948-0.998kg
fat coal(bituminous one)	0.930kg
Lignite	0.988-1.140kg

Eventually, the average CFP as the final result of CFP is 1kW·h (C_i):

$$C_i=\frac{1.004+1.049+0.948+0.998+0.930+0.988+1.140}{7}=1.008kg$$

Data about rolling and stamping

About Dell-2U product, there are 3 different styles: large piece, medium piece, and small piece. For each style, there are more than 10 sequential stations in the production line. For each station the rated power, holding power and working power was collected from related machines. Then videos were taken to check how many parts were made in one minute.

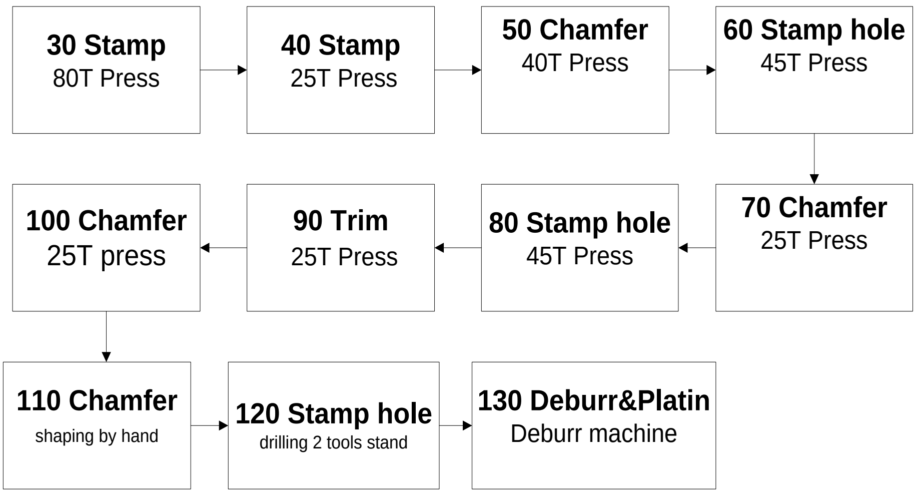


Figure 6: flow of large piece

Take the large piece as an example:

Table 4: data about rolling and stamping

Station	**Machine**	**Parts Made**	**SPM** (stamps per minute)	**Time per stamp(s)**	**…**
L-20	rolling RF007	10	10	4.5	…
L-30	80T	15	15	0.6675	…
L-40	25T	17	17	0.4825	…
L-50	40T	16	16	0.485	…
L-60	45T	12	12	0.5175	…
…	…	…	…	…	…

Data about environmental consumption

For the environment measurement the ceiling fan, floor fan, wall fan, axial fan, exhaust fan and air compressor were considered. With that the rated power of each machine is obtained.

Table 5: data about environmental consumption

ceiling fan	floor fan	wall fan	axial fan	exhaust fan	air compressor
1680	4160	2420	8000	750	141000
1440	1680	0	2200	0	74000
3120	5840	2420	10200	750	215000

Data about packaging

For this part, different kinds of materials are used for packaging, for example cardboard, foam, cellophane and so on. First, the carbon dioxide emission factors must be found for each of them, and then measure the weight, finally the CFP is found.

Table 6: CFP emission factors of different kinds of materials

	cardboard coeff (kg/kg)	foam coeff (kg/kg)	steel coeff (kg/kg)	cellophane coeff (kg)
low	0.732	4	1.65	2.2
high	0.809	4.8	1.83	2.6

Table 7: weight measurement of packaging parts

single package	mass 1 (kg)	mass 2 (kg)	mass 3 (kg)	mass 4 (kg)	mass 5 (kg)
cardboard	0.3495	0.349	0.348	0.35	0.349

Foam	0.0735	0.072	0.0725	0.075	0.0735
steel left	1.557	1.5585	1.5565	1.5565	1.5555
steel right	1.5475	1.559	1.547	1.5605	1.5615

5.Project Results

Preliminary results

CFP of Parts Producing

First, calculate CFP of each station for every piece: large, medium, and small.
The Large piece for example:

Table 8: CFP per hour for each station in large piece

Station	Machine	CFP per hour (1min)/kg
L-30	80T	2.327962
L-40	25T	1.160475
L-50	40T	1.1373
L-60	45T	3.478056
L-70	25T	0.982602
L-80	45T	3.427618
L-90	25T	1.041893
L-100	25T	1.133287

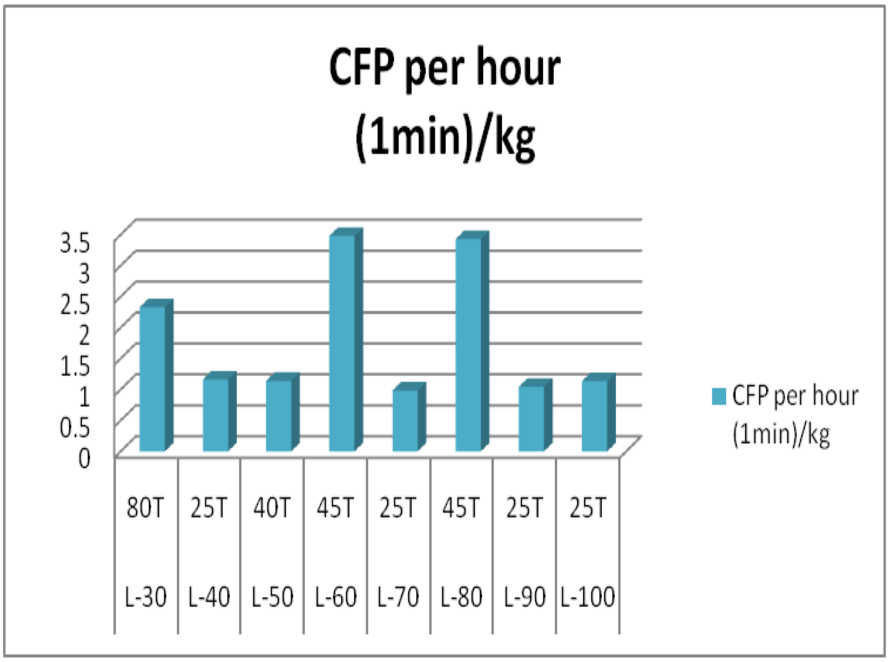


Figure 6: CFP of each station for large piece

From the figure above, it can clearly be seen that the L-60 station produces the most CFP in the large piece production, the related stamping machine—45T machine needs optimizing.

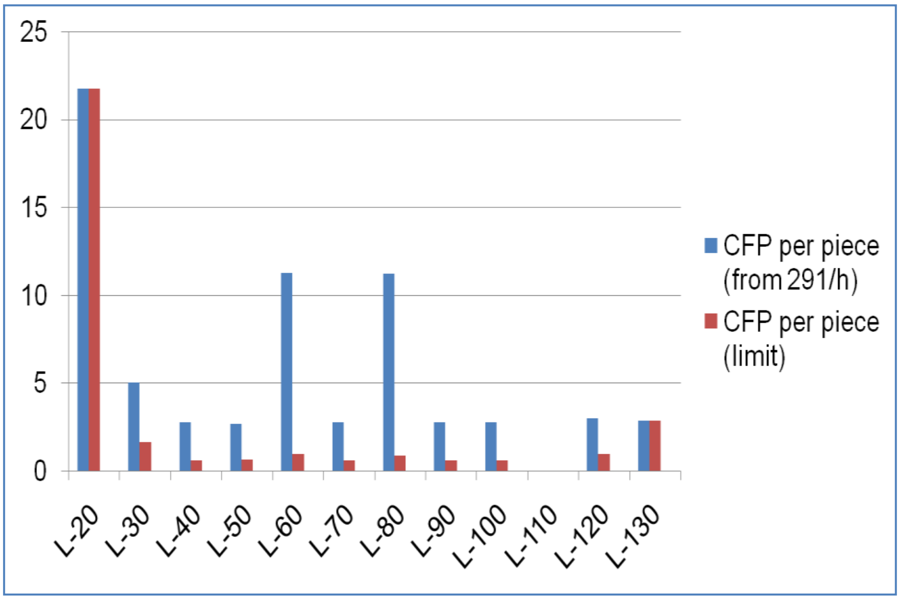


Figure 7: comparison between current CFP and the limit

From the figure above, if the stamping machines are working in ideal conditions, the CFP they emit will be much less.

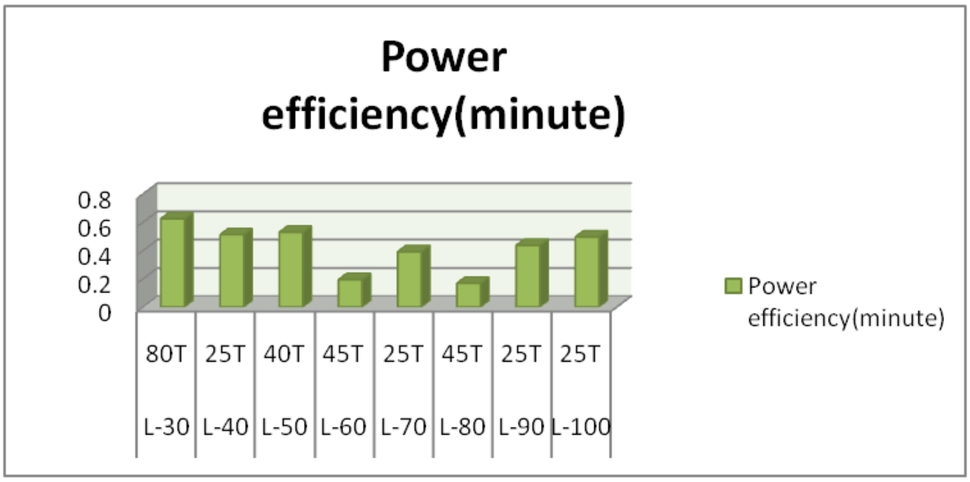


Figure 8: power efficiency of each station for large piece

From the figure above, machine 45T has the least efficiency. Improving it will be a goal in the later work.

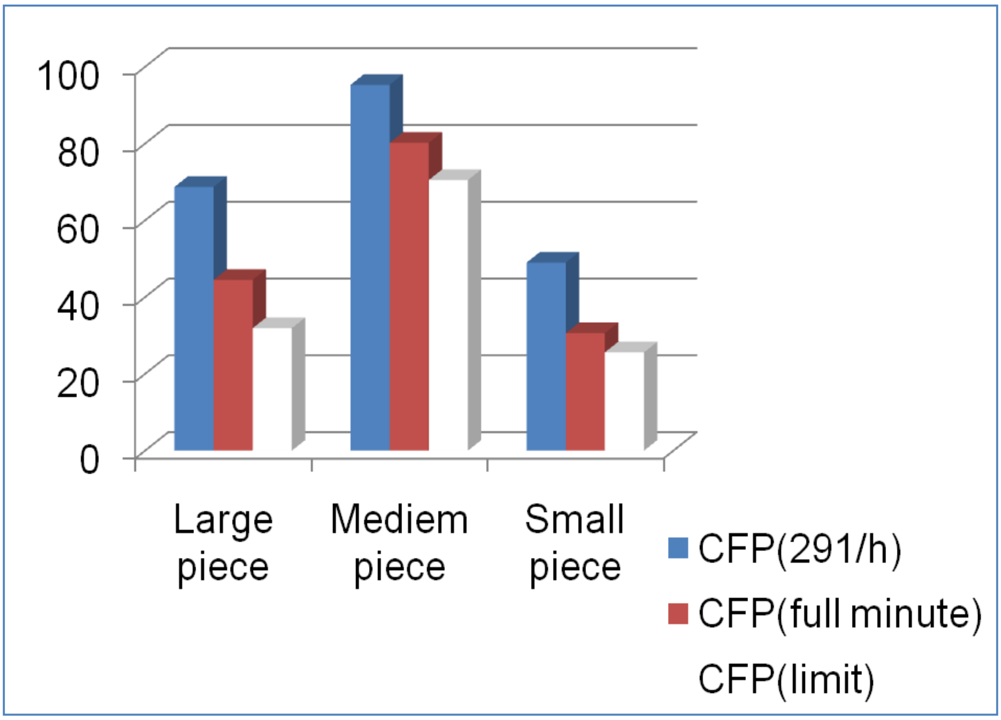


Figure 9 difference between the three CFP values

- The difference between the three CFP values comes from the difference in holding time.
- The CFP in parts production can be greatly decreased.

CFP of packaging

	per single package carbon footprint (kg)	
cardboard	0.25	0.28
foam	0.2932	0.35
steel	5.13	5.69
total	5.68	6.32

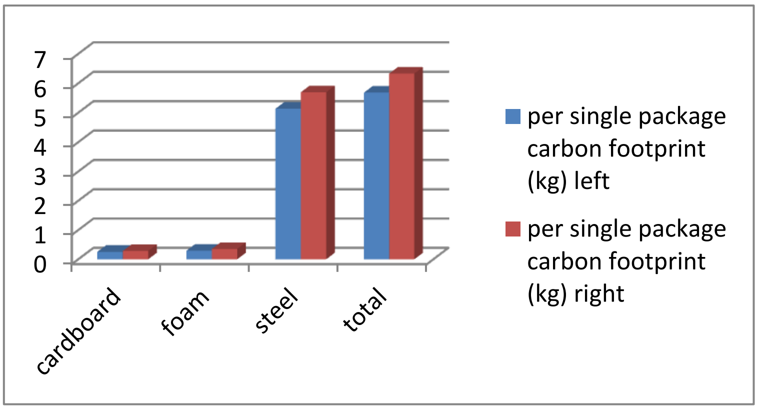


Figure 10: CFP of per single package

According to the table and graph above, it can be concluded that steel plays a very important role in the emission of CFP for packaging part.

	per shipment package carbon footprint (kg)	
cardboard	29.78	32.91
foam	25.8	30.96
steel	451.84	501.14
cellophane	0.82	0.96
total	508.25	565.98

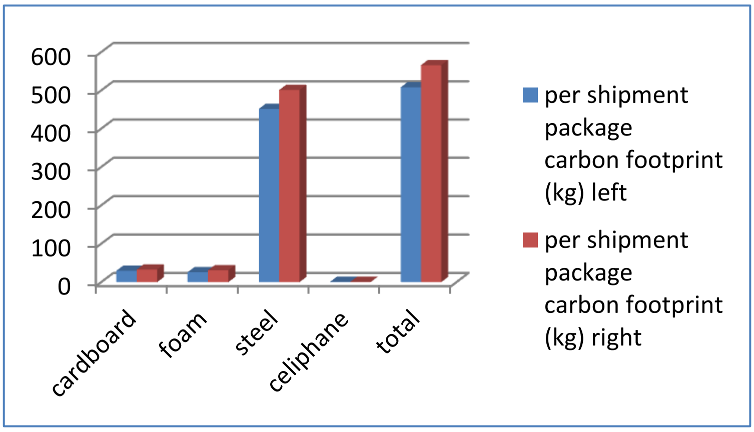


Figure 11: CFP of per shipment package

The table and graph reveal that steel accounts for a large proportion of CFP

Final results

Eventually, CFP of every part is found. The total CFP of one pair is **8301g**.

Table 9: CFP Analysis of DELL_2U

CFP Analysis of DELL_2U						
category	Raw Material	Parts Producing	Transportation	Packaging	Environmental Consumption	total
CFP(per pair)(g)	5414.7	426.1	0.66	688.9	1770.6	8301.0
Ratio (%)	65.2	5.	0.007	8.2	21.3	100

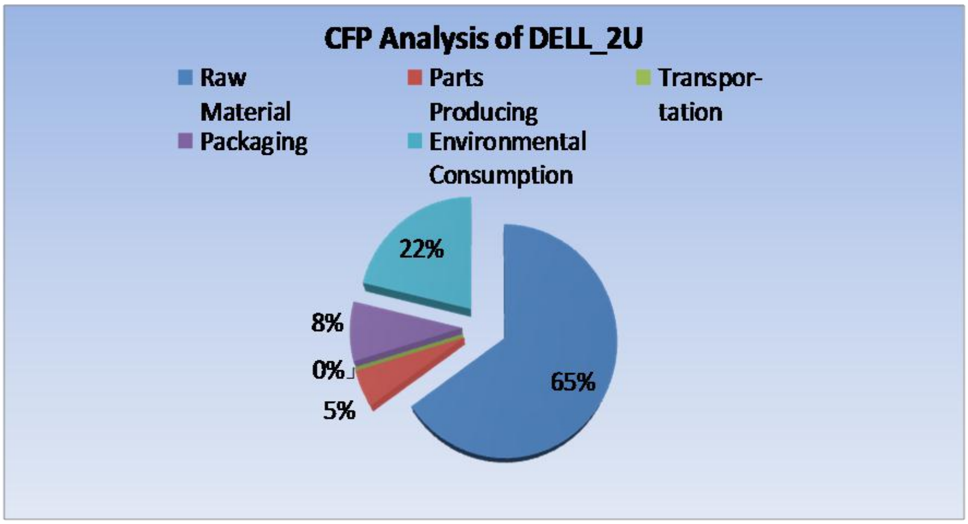


Figure 12: CFP analysis of DELL_2U

As it can be seen from the chart, the main CFP of the DELL-2U is produced by raw material, which accounts for 65% of its total carbon footprint. The next two significant CFP-producing items are environmental consumption and packaging, which are 22% and 8% respectively.

6.Optimizations

Parts producing

The machine is always on, while only part of the time is meaningful.

Take the stamping machine for example:

Figure 13 stamping machine

Table 10 SPM of each station

Station	Machine	Parts Made	SPM (stamps per minute)	Time per stamp	Actual working rate
				s	%
L-20	rolling RF007	10	10	4.5	75.00
L-30	80T	15	15	0.6675	16.69
L-40	25T	17	17	0.4825	13.67
L-50	40T	16	16	0.485	12.93
L-60	45T	12	12	0.5175	10.35
L-70	25T	11	11	0.4825	8.84
L-80	25T	11	11	0.4825	8.84
L-90	25T	13	13	0.4825	10.45
L-100	25T	16	16	0.485	12.93

Problem:

The holding time is long, during which the machine consumes electricity but does not make a difference.

	Actual working rate	Efficiency
25T	9.05%	37%
40T	32.28%	52%
45T	9.60%	19%
80T	14.53%	57%

Figure 14 efficiency of different machines

Solutions:

Change or redesign the inefficient machine.

Type	Working current（A）	No-load current（A）	Force（KN）	Die height（mm）	Height adjustment（mm）	Motor powe（KW）
OCP-45N	9.6	5.4	450	240	60	5.5
JE21-40C	7	1.1	400	270	60	4

Figure 15 change the inefficient machine

Problem: the no-load current of OCP-45N is large, thus consuming more electricity but making no difference.

Suggestion: replace the OCP-45N with JE21-40C

Proof: the force and die height of JE21-40C can meet the requirement of stamping.

Purpose: save electricity and reduce carbon emissions.

Automatic feeder designing

M-100 M-110

Figure 16 automatic feeder designing

M100-M110 are the weakest links according to the video we take.

Station	Machine	Parts Made	SPM (stamps per minute)	Time per stamp
				s
M-90	25T	10	5	0.55
M-100	80T	13	13	0.8825
M-110	25T	14	7	0.55
M-120	40T	10	5	0.55

Figure 17 the weakest links

From the video analysis we see that M-110 is always waiting for M-100.

The propose of designing the feeding machine is to reduce the time of holding, thus reducing each piece of the CFP.

The principle is to reduce the holding time of the machine thus reduce the unused power consumption, decreasing the CFP per piece. Feeding the machine automatically will save one worker at the same time.

Use a cylinder to move left and right, another cylinder to do the up and down drive, Linear bearing to hold the whole thing. The whole bearing moves up and down, instead of only the hand moves, use a middle station cylinder to make up the difference between the heights of the two stamping machines. Use a PLC to do the control. Install the linear bearing reversely, which means slider mounted face up while the rail sits on top. The bearing and cylinder are installed in the throat of the crank press.

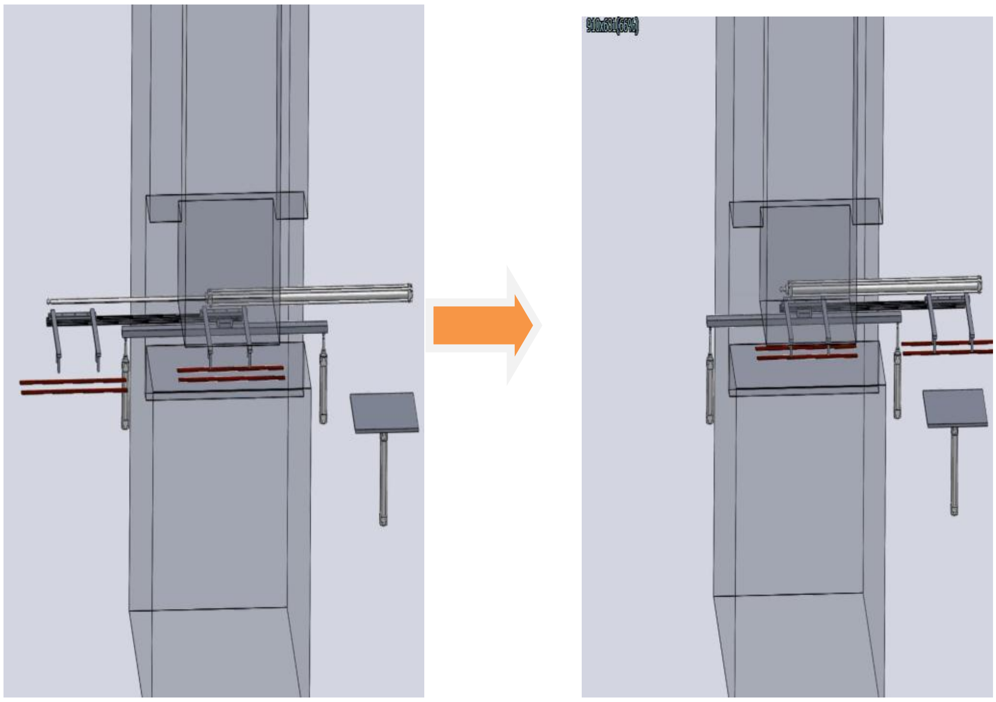
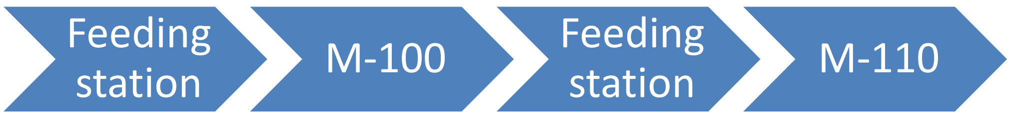


Figure 18 feeding machine

The main flow chart:



PLC control:

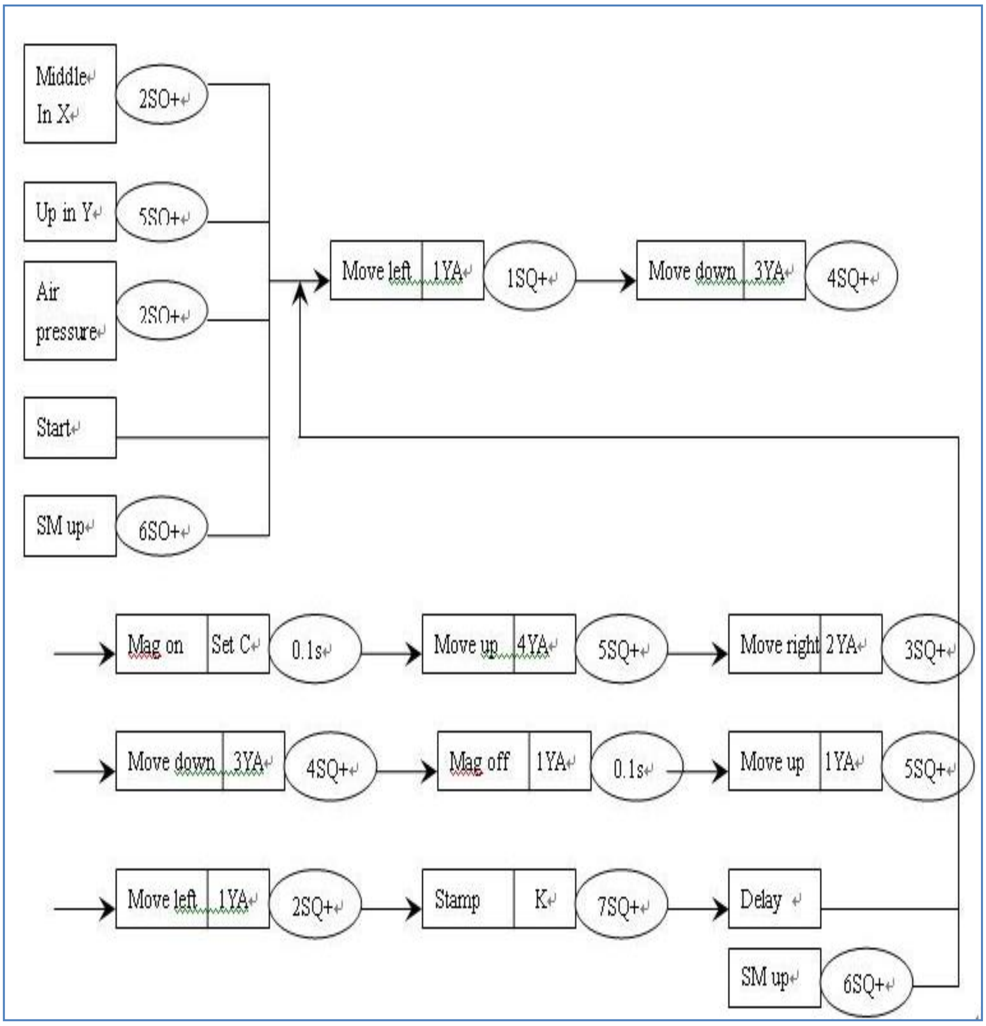


Figure 19 PLC control

Efficiency analysis

Assumptions:

- The feeder cost no more than 100k RMB;
- Cost of worker:2000 per month
- Electricity price: 0.8/kwh

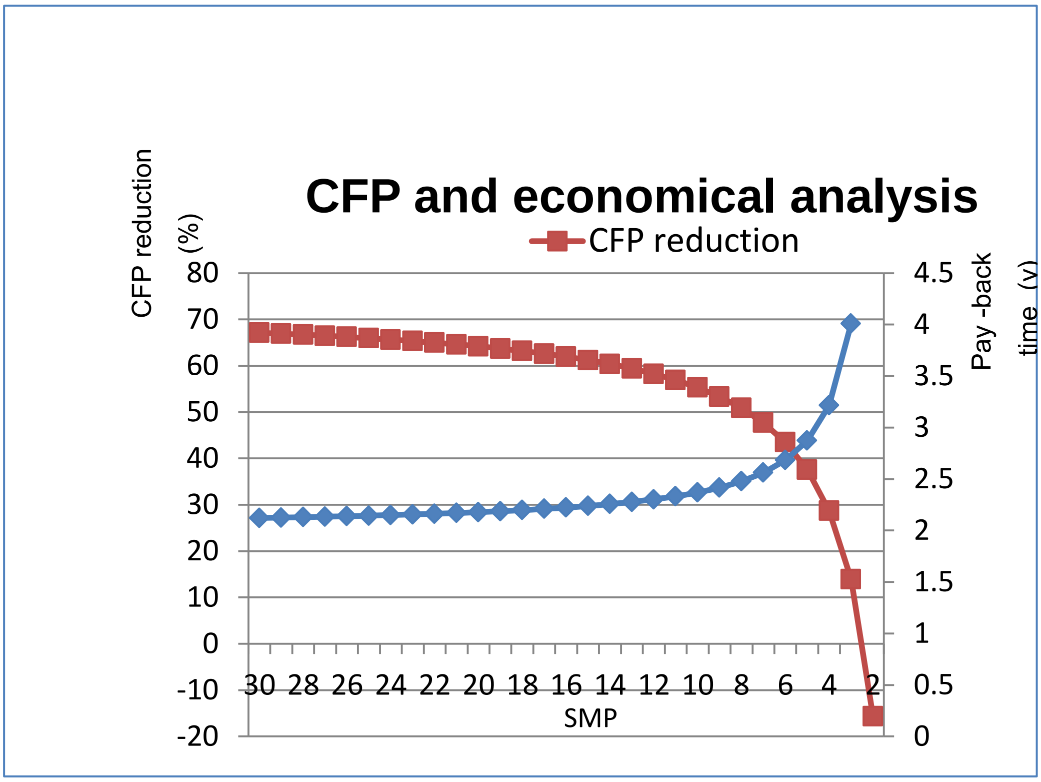


Figure 20 CFP and economical analysis

Magnet hand tool updating

A device that helps load the 80T machine and others like it.

Notice due to its low clearance only one piece is placed into the machine when it has room for two. Two different devices were designed to make this station more efficient.

Figure 21 current situation

The first design is a four bar linkage on a piston that accurately places the parts into the machine. While the machine is pressing the device will remain in the stamp. Then pull out and remove stamped rails and place new ones on.

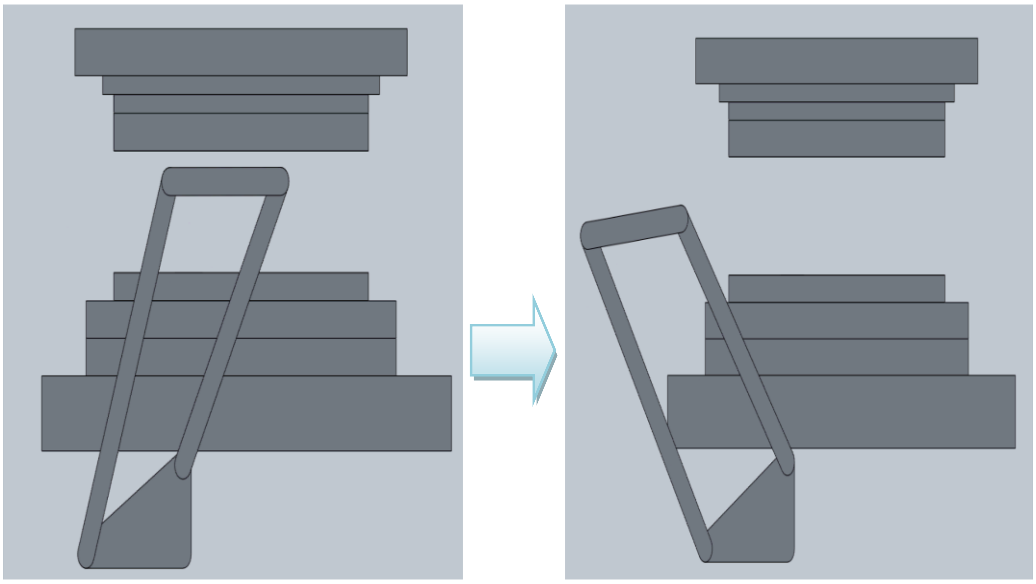


Figure 22 four bar linkage

Another new hand tool is seen below. This idea is much cheaper than the first although it is more cumbersome. To use place into machine then twist the handles to drop the rails, stamp then remove the same way they were placed in.

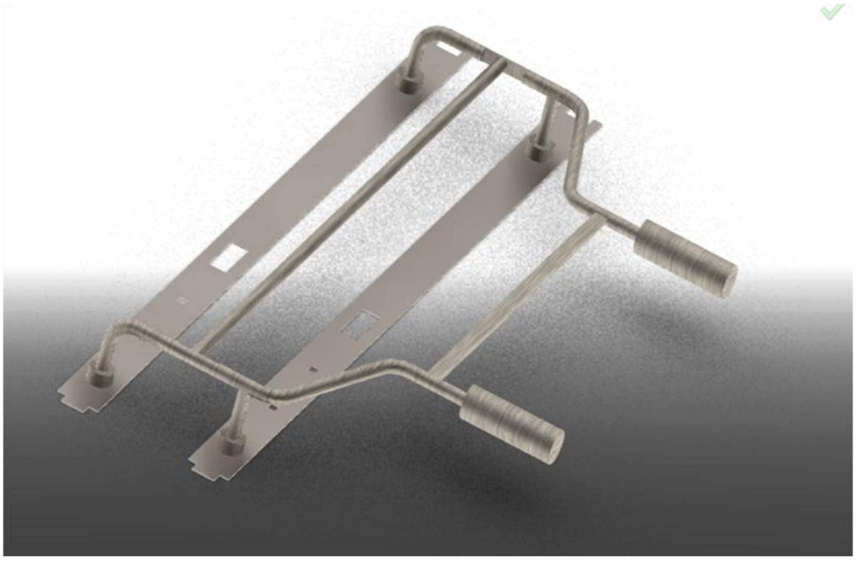


Figure 23 hand tool design

If these ideas were created they will effectively double the efficiency of the machine removing 17% of the CFP at this station per stamp.

Environmental consumption

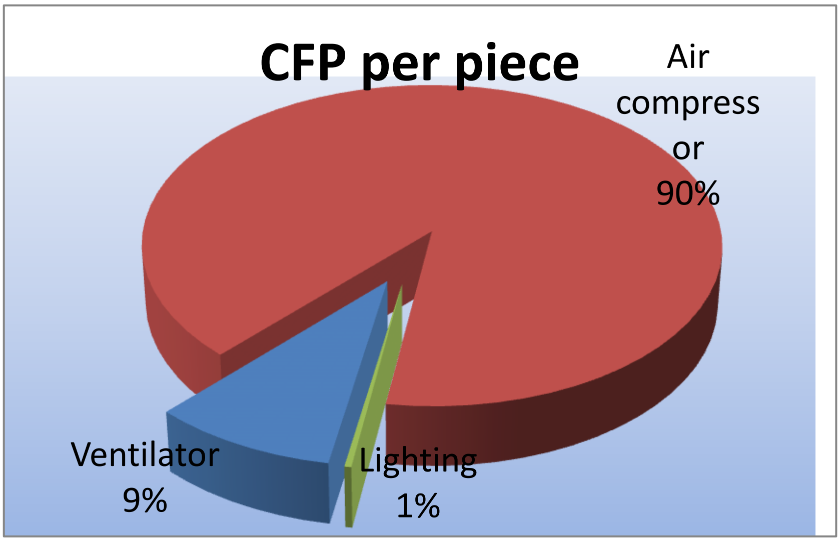


Figure 24 CFP per piece

Air compressor consumes the largest CFP share of Environmental consumption.

Reduce the air consumption:

- Reduce the leakage;
- Reduce the excessive release of air.

Air pipe

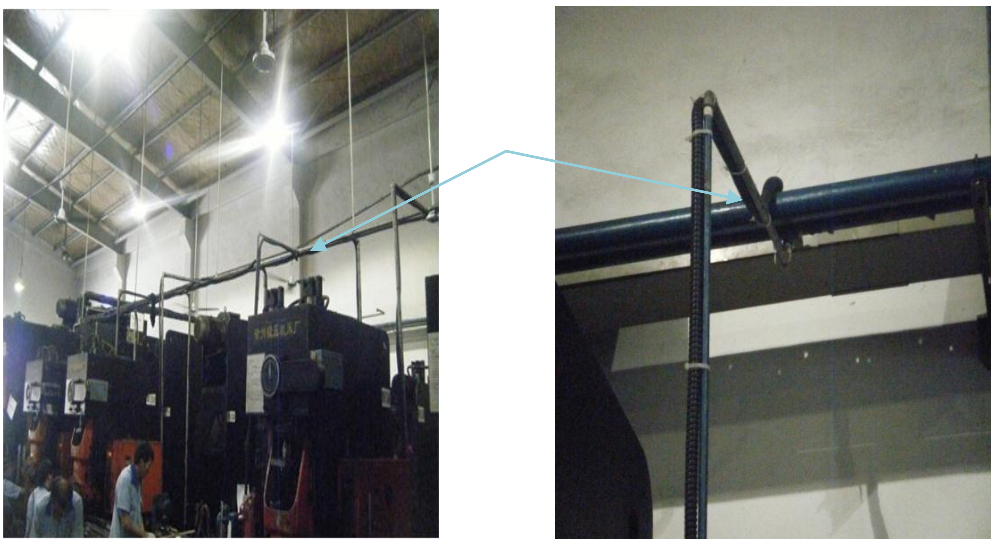


Figure 25 air pipe

Connectors are directly down.

Problems: water and dust depositing in main air pipe directly get into the intake manifold

- Water makes machines easy to rust. Oil mixed with water will reduce the lubricating effect, increase wear of machines and shorten the life of machines.
- Dust may block up air valves, increase air flow resistance and wear of machines.
- Damage to the machine extend the production time, resulting in an increase in carbon

emissions, on the other hand increase maintenance costs.

Suggestion: Turn the connector up.

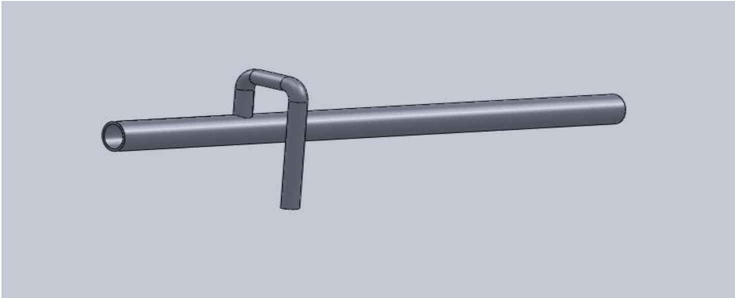


Figure 26 turn the connector up

Using the connector the amount of water and dust from getting into the intake manifold above it should effectively decrease. This reduces the failure rate of machine and electricity consumption, thus reducing carbon emissions of product.

Outlet valve

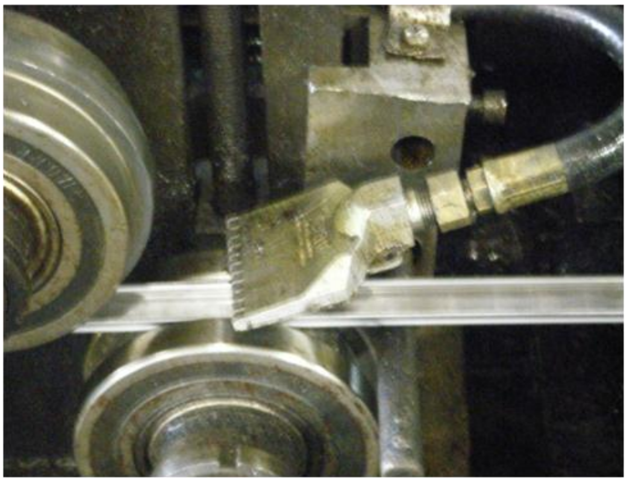


Figure 27 outlet valve

Function: Blow away saponification liquid on the slides

Problem: Air flow quantity can only be determined by the main airway, it cannot be adjusted according to the actual production conditions, such as producing big, medium, or small ones.

Suggestion: install adjustable throttle valve before the outlet

Figure 28 adjustable throttle

Purpose: Adjust the air flow quantity according to actual production conditions

Price: 10~100 yuan.

Air pipe not in use

Figure 29 air pipe not in use

Suggestion: Remove the air pipe not in use or install valve at the joint to shut off the air flow.

Purpose: Reduce the gas leakage caused by these useless pipes, thus reducing electricity consumed by air compressor and carbon emissions.

Air compressor

Problem:

- ✓ No-load time: working time is 20:1
- ✓ If one cannot work, some stamping machine must stop working

- ✓ Extend the production time and waste energy

Suggestion:

- ✓ Purchase one more air compressor to make them work by turn

7.References

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3 Wang wei, Lin jianyi, Cui shenghui, Lin tao, An Overview of Carbon Footprint Analysis, Environmental Science & Technology, 1003-6504(2010)07-0071-08

4 Ji junping, Ma xiaoming, Review of Carbon Footprint: Defi nitions and Accounting Methods, low-carbon economy, 2011（4）：76～80.

5 http://www.baidu5678.com/hemeihongganji/hm146081.html

6 Wenmin Chen, Industrial analysis and elemental analysis using the results of the calculation of calorific value of coal in China, Beijing Research Institute of Coal

7 Documentation for Emissions of Greenhouse Gases in the U.S. 2005

8 http://www.eia.gov/oiaf/1605/coefficients.html#tbl2

8.Addenda

CFP calculation for medium size.

Table 11: CFP of each station for medium piece

Station	CFP per piece (for 1 min)	CFP per piece (limit)
M-30	3.079855	1.970987
M-35	0	0
M-40	1.300235	0.709806
M-50	1.478313	0.793692
M-60	1.750068	1.750068
M-70	1.025303	1.025303
M-80	1.25745	0.709806
M-90	1.375774	0.663514
M-100	3.223401	2.134228
M-110	1.063155	0.663514

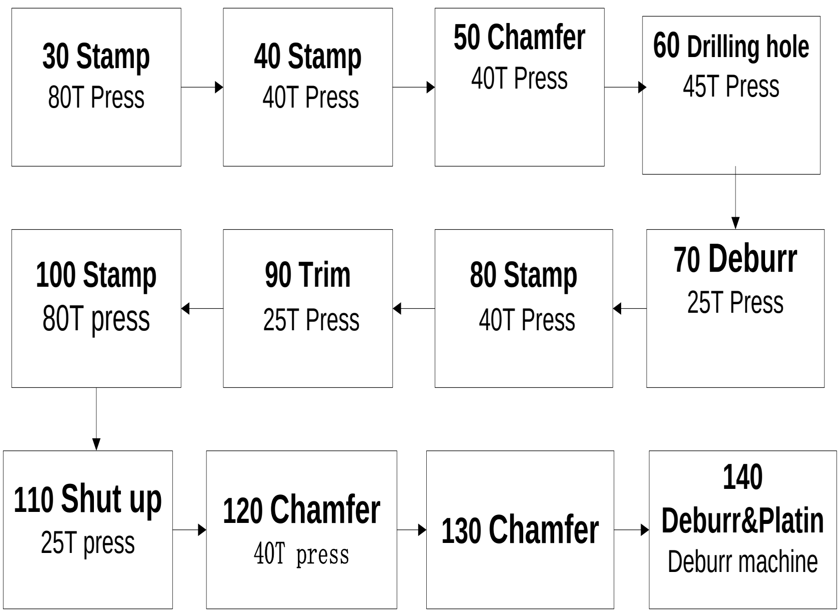
M-120	1.334673	0.709806
M-130	1.553874	0.880804
M-135	1.735128	1.735128
M-140	1.557912	0.663514
M-150	0	0
M-160	0.161053	0.161053
M-170	1.447667	0.087463
M-180	0	0
M-190	0.663431	0.663431
M-200	2.505196	2.505196

CFP calculation for small size.

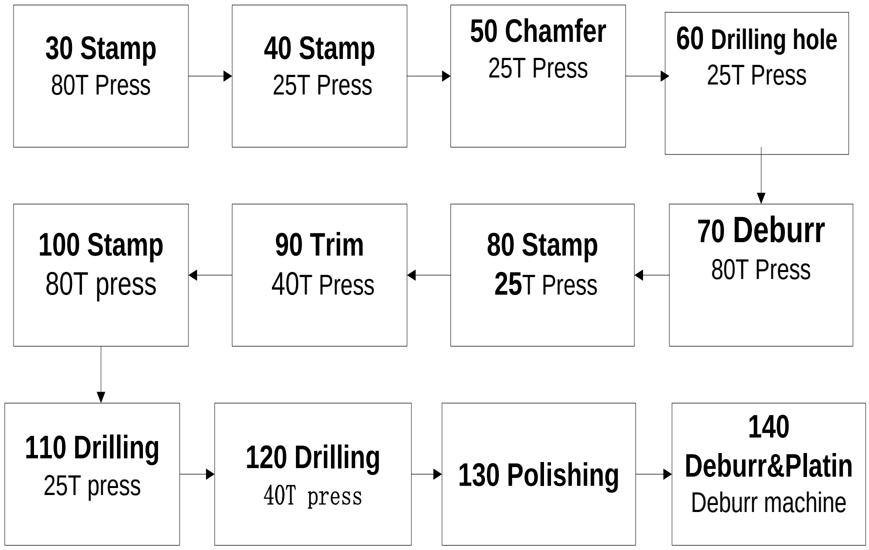
Table 12: CFP of each station for medium piece

Station	CFP per piece (for 1 min)	CFP per piece (limit)
S-30	1.75551	1.65055
S-40	0.828691	0.663514
S-50	0.965462	0.663514
S-60	0.965462	0.663514
S-70	2.119728	1.977033
S-80	0.906118	0.702722
S-90	1.333011	0.796918
S-100	0.218356	0.218356
S-110	0.067256	0.134512
S-120	0.405347	0.202673
S-130	3.276026	3.276026
S-140	1.409792	1.409792

Medium size:



Small size:


30 Stamp
80T Press
40 Stamp
25T Press
50 Chamfer
25T Press
60 Drilling hole
25T Press
70 Deburr
80T Press
80 Stamp
25T Press
90 Trim
40T Press
100 Stamp
80T press
110 Drilling
25T press
120 Drilling
40T press
130 Polishing
140
Deburr&Platin
Deburr machine