Cost analysis of the railway composite brake shoe engineering essay

According to the input information given by Mechanical Engineering department team, the required analysis & evaluation has been done. The scope is to determine the cause of the brake shoe failure like stress concentration and fatigue and optimize to prevent it.

Some of the options to reduce fatigue failure can be either to add-in some materials to the process, or increasing/decreasing the material composition percentage, or small changes in the manufacturing process will improve the efficiency of brake in terms of longer life.

5. 1 Objective

The aim of this project is to provide cost analysis for the manufacturing process involved in producing the railway composite brake shoes. The current price for purchasing one composite brake shoe is approximately $ 10. 52. The group is assigned to compare the cost of buying the brake shoes from outside and cost of building the brake shoes. And the group has to come up with the better results of the evaluation. The focus is to reduce the cost and increase the life of the brake shoes. This is discussed in the graph shown below in Fig. 29.

Fig 29. Objective of the project

6. Manufacturing Process Analysis

6. 1 Background

A manufacturing process [4] is defined as the use of one or more physical mechanisms to transform the shape of a material’s shape and/or form and/or properties. The selection as to which process should apply to particular material, is influenced by a number of factors, which affect cost, production rate, flexibility and part quality.

6. 2 Literature review

Gilbert et al (1976) provided the system for manufacturing friction elements (U. S. Patent 3, 998, 573). They provided different material composition used for manufacturing railway brake shoes. Also, it explains about the basic process in producing the brake shoes. The method includes compression molding, stamping and thermal curing of resin. In this invention, ideas of using high pressure to produce friction elements from an essentially dry mixture were described.

Raj Velayutha (2002) provides insights of polymer based backing plate for railway brake shoes and disc pads (US 2002/0179384 A1). In this invention, polymer based brake shoes were given importance when compared to steel plates because of its high demand and more life expectancy. Material components were discussed in this work but it does not explain about the manufacturing process involved in it.

Nakamura, R. and Fukuoka, K. (1966) provides method for manufacturing railway composite brake shoes. Metallic molding, stoving and curing process were discussed in this paper. Design, dry system manufacturing procedure, metallic mold construction, and bonding of back metal to base material used in production of high friction and low friction type of brake shoes are described; optimum production process and one-stroke automatic molding die were developed; new modified phenol-formaldehyde was developed as thermosetting resin; bonding between molded part of brake shoe and back metal was obtained through appropriate selection of gelation time for bonding agent and breathing time under initial pressure relation between compounded materials and friction characteristics.

6. 3 Manufacturing process for composite railway brake shoes

There are about nine process involving in manufacturing railway brake shoes. They are coming as follows:

Fig 30. Production Process for railway brake shoes

First, the raw materials will be coming to the factory in container boxes through trucks. Then it will be loaded and unloaded by the common labors. Considered, the number of working hours in the manufacturing industry is 8 hours/day for a shift. Second, the raw materials should be weighted using floor type weighing scale and it needs to weigh up to 200 kilograms. Third, it has to undergo mixing of materials such as Graphite powder, Phenol formaldehyde resin, kaolin, rubber flakes and asbestos fibers. The act of blending components together thoroughly is called as blending process. The machine used in this process is called V-Blender.

Four, it will undergo a process named pre-heating in which materials will be heated in an industrial electric furnace. Depending on the type of metal, sometimes it is necessary to preheat the base metal to lessen distortion, to prevent spalling or cracking, and to avoid thermal shock. At this stage, a back plate should be attached to the brake lining material. It also requires the slight heating process. After it comes from the electrical furnace, it will pass on to the next stage which is molding process. It is the process used in manufacturing to shape the materials.

Then Initial pressure has to be applied to minimize the extent of flash and improve the bonding between back metal and base material. The best effect of initial breathing can be secured if it is done at the time when the resin has become plastic under initial pressure and the molded surface area of brake shoes has hardened about 70% [4]. The breathing has to be well-timed because imperfect breathing can cause cracking in the side or core of brake shoe.

Six, it will undergo stoving and curing process. Stoving is a process in which pods are placed at once between covers of laine in large cases during twelve to fourteen hours; thus maintained with the heat [5]. Then it comes curing, which is a term in polymer chemistry & process engineering that refers to the toughening or hardening of a polymer material by cross-linking of polymer chains, brought about by chemical additives, ultraviolet radiations, electron beam or heat [6]. In this production process, perfect curing should be done in the subsequent stage of stoving.

Before stoving, the hardness distribution differed depending on the molding time; but after stoving, it will get the uniform shape. At this stage, shoes are molded at a pressure of 100 t and locked for 15 minutes at 140 degree Celsius; the stoving lasted 6 hours at 140 degree Celsius. After this process, Inspection should be carried out and then the product will be packed in boxes for delivery.

6. 4 Machine Selection

For each process step, the machine selection and the parameters are shown as following:

Machine cost includes purchase of machines, installation of machines, shipping, etc. The estimation of machine cost is based on the prices of machine from the suppliers, with a 15%-30% adjustment of the original prices. The prices are from a b2b global trade website: www. industrialfurnaces. com and www. alibaba. com. The machine selection and the parameters are shown as following in Table 9.

Table 9. Machine selection and parameters

Unloading & Loading of Raw Materials

Number of Common labors assigned to this activity = 3

Processing time in hours per month = 24

Weighing Process

Floor type Weighing Scale

Common labors assigned to this process = 1

Processing time in hours per month = 48

Total cost of the machine = $263

Blending Process

V-Blender

Model: – Gemco TWIN SHELL 30cu. ft. V Blender

Skilled Workers assigned to this process = 2

Processing time in hours per month = 112

Total cost of the machine = $ 19, 550

Pre-heating Process

Industrial Electric Furnace

Model: – Lindberg Industrial Electric Furnace

Skilled Workers assigned to this process = 2

Dimension: design according to the customers

Processing time in hours per month = 96

Total cost of the machine = $ 25, 000

Pre-heating(Back plate attachment)

Skilled Workers assigned to this process = 1

Processing time in hours per month = 192

Total cost of the machine = $ 15, 000

Molding Process

One stroke automatic molding die.

Model: – fully computerized Automatic molding machine.

Skilled Workers assigned to this process = 1

Dimension: design according to the customers

Processing time in hours per month = 192

Total cost of the machine = $ 100, 000

Composite Curing Oven

Stoving & Curing Process

Model: – Composite Curing Oven.

Skilled Workers assigned to this process = 1

Dimension: design according to the customers

Processing time in hours per month = 144

Total cost of the machine = $ 25, 000

Inspection process

Skilled Workers assigned to this process = 1

Dimension: design according to the customers

Processing time in hours per month = 192

The equipment used here for inspection is Go and No-Go gauge

Total cost of the machine = $ 1, 000

Finishing & Packaging Process

Common Workers assigned to this process = 2

Processing time in hours per month = 192

7. Cost Analysis

7. 1 Estimated demand for brake shoes for Norfolk Southern Railways

Table 10. Demand estimation for old design

Amount

Unit

Formula

B1. Freight train miles traveled [8]

80 million

miles/year

B2. Total number of freight cars NF operating [8]

94, 660

Cars

B3. Average number of cars each train has

120

Cars

B4. Total number of trains NF operating

789

Trains

B2/B3

B5. Mileage per train operating each year

101, 394

miles/train/year

B1/B4

B6. Mileage between two maintenance

10, 000

Miles

B7. Times of maintenance

10

times/train/year

B5/B6

B8. Number of brake shoes used per train

960

Per year/train

(8)*B3

B9. Total number of brake shoes inspected per year per train

9, 600

shoe/train/year

B7*B8

B10. Percentage being replaced

5 %

Brake

B11. Number of brake shoes replaced per year per train

480

shoes/train/year

B9*B10

B12. Plant Size (ANNUAL DEMAND)

378, 720

brake shoe

B11*B4

B13. Plant Size (MONTHLY DEMAND)

31, 560

brake shoe

B12/(12)

Price of one composite brake shoe available in market

$ 10. 52 (approximately)

Cost if buying brake shoes per year

$ 3, 984, 134. 4

B12* ($10. 52)

B3 values are based on observations.

B1 and B2 values taken from Norfolk Southern 10k annual report 2008

B6 and B10 values are coming from Dr. Kim

Based on the estimation of demand in Table 5. 1, the annual demand of brake shoes or plant size can be estimated by the following formula:

Annual Demand = (Number of brake shoes replaced per year per train)*(Total number of trains NF operating)

According to this formula, the annual demand of composite brake shoes is 378, 720 pieces; while the monthly demand is 31, 560 pieces. The average price for each composite brake shoe is $ 10. 52, which will make a cost of $ 3, 984, 134 per year for the brake shoes purchasing.

7. 2 Capacity estimate

Table 11. Capacity estimation

Process

Name of machines

Number of machines

Number of common workers

Number of skilled workers

Engineers and supervisors

Processing time in hours per month

Unloading and loading of raw material

N/A

0

3

0

0

24

Weighing

Floor type weighing scale

1

1

0

0

48

Blending

V-blender

1

0

2

1

112

Pre-heating

Industrial electric furnace

1

0

3

0

288

Molding

One stroke automatic molding die

1

0

1

1

192

Stoving & curing

Composite curing oven

1

0

1

1

144

Inspection

Inspection equipment

1

0

1

1

192

Finishing & Packaging

Packing equipment

1

2

0

0

192

7. 3 Machine Cost

Machine cost includes purchase of machines, installation of machines, shipping, etc. The estimation of machine cost is based on the prices of machine from the suppliers, with a 15%-30% adjustment of the original prices. The prices are from a b2b glabal trade website: www. alibaba. com. The estimation of machine cost is shown in Table 12.

Table 12. Machine cost estimation

Name of machines	Number of machines	Cost
Floor type weighing scale	1	$263
V-blender	1	$19, 550
Industrial electric furnace	1	$40, 000

One stroke automatic molding die

1

$100, 000

Composite curing oven

1

$25, 000

Inspection equipment

1

$1, 000

Packing equipment

1

$1, 000

Total

$186, 813

7. 4 Building Cost

Table 13. Building cost estimation

Name of machines

Number of machines

Space required

Unloading dock

0

740

Floor type weighing Scale

1

26

V-Blender

1

90

Industrial Electric Furnace

1

85

Pre-heating (Back plate attachment)

1

65

fully computerized Automatic molding machine

1

150

Composite Curing Oven

1

240

Go and No-Go gauge inspection station

1

200

Finishing & Packing device

1

520

Loading dock

1

600

Inventory

2716

Total building space

6518. 4

Total building cost

$977, 760

The space required for inventory is assumed as the same as for all the production based on the observation from production practice. The total building area is nothing but the summation of production area and (Inventory area + Space allowances) because of the transportation and other usage. The commercial building cost per square feet is $150 from the website http://www. reedconstructiondata. com/news/2009/03/the-cost-of-building-green/.

Therefore, the total building cost is $150*(6518 square foot) = $977, 760.

7. 5 Labor cost

Based on the educated guess, team is considering total of three common workers for unloading & loading operations.

The team is considering 1 shift of work in the factory which is eight hours per day. The total raw materials coming to the manufacturing facility for a month weighs 176, 000 kg. Hence for a single day it is 5866. 66 kg. According to Health and Safety Fact sheet for manual handling, a male person can lift 25 kg load in a single time and 16 kg for female. The team selects only male workers for this job.

Therefore, number of times for unloading the materials from the truck =

(5866. 66/25)

= 234. 66 times

Two labors assigned for transferring the objects from truck to the fork lift. So, each person lifts and moves the item for about 117 times. And one labor is assigned for operating the fork lift, which travels from truck point to the workplace or inventory storage place.

The same numbers of workers are being used for loading operations as well. Two common workers allocated for transferring the products from fork lift to the truck. While one worker for driving the forklifts within the industry.

Table 14. Labor cost estimation

Labor cost

Common workers (pay by hour)

Skilled workers (pay by hour)

Engineers and supervisors (pay by salary)

Sub total

Total number of labor

6

8

4

Training cost (annual)

$6, 000

$16, 000

$20, 000

$42, 000

Regular Payment

$8. 5

$10. 5

$60, 000

Overtime Payment

$12. 8

$15. 8

N/A

Regular working hours per day

8

8

Overtime working hours per day

0

0

Working days per year

288

288

Annual payment

$117, 504

$193, 536

$240, 000

$551, 040

Total

$593, 040

In Table 14, assume that the manufacturing plant is running 8 hr shifts for 24 days a month. From what we have discussed above we have 6 common workers who are paid $8. 50 per hour, 8 skilled workers who are paid $10. 50 per hour. Also there are 4 engineers/supervisors with a $45, 000 per annum salary. Therefore, the annual labor cost including the training cost and payment is $593, 040.

7. 6 Materials Cost

Monthly demand of brake shoes is 32000. Weight of brake shoe estimated is 11 lb. Thus, total weight of brake shoes produced in the entire month is 352, 000 lb. considering a 10% extra purchase for allowances of material wastage, the total weight of raw materials required is 1. 1 * 352, 000 lb= 387, 200 lb. Now, the total weight of the composition of materials according to percentage by weight is given by,

Novolak (13% of total raw materials) = 50, 336 lb

Iron Powder (24% of total raw materials) = 92, 928 lb

Graphite Powder (22% of total raw materials) = 38, 720 kg

Asbestos (12% of total raw materials) = 46, 464 lb

Rubber Flakes (13% of total raw materials) = 50, 336 lb

Kaolin (16% of total raw materials) = 28, 101 kg

Therefore, the cost of each material is shown in Table 15.

Table 15. Material cost estimation

Name of the material

Amount per piece (lb)

Total weights (lb)

Price per pound

Subtotal

Novolak

0. 14

54157

$0. 24

$12, 998

Iron Powder

0. 26

99982

$0. 32

$31, 994

Graphite Powder

0. 24

91650

$0. 45

$41, 659

Asbestos

0. 13

49991

$0. 10

$4, 999

Rubber Flakes

0. 14

54157

$0. 10

$5, 416

Kaolin

0. 18

66655

$0. 11

$7, 120

Total

$104, 186

Therefore, total cost of raw materials per year $ 104, 186.

7. 7 Utilities cost

Table 16. Utilities cost estimation

Name of machines	Number of machines	Power (KW)
Floor Type Weighing Scale	1	0. 105
Gemco TWIN SHELL 30cu. ft. V Blender	1	38
Lindberg Industrial Electric Furnace	1	70
Pre-heating(back plate attachment) equipment	1	30

fully computerized Automatic molding machine

1

35

Composite Curing Oven

1

58

Testing/Inspection device

1

5

Packaging device

1

275

Total utilities cost

$1, 177, 586

The unit price for industrial electricity in the US is 6. 89cents/kWh based on the following website. http://www. eia. doe. gov/cneaf/electricity/epm/tablees1a. html. Number of machine working days in a year is 288 days and 8 hours per day.

Therefore, utilities cost = 0. 0689*(number of machine working hours in a year)*(total power of all machines) = $1, 177, 586.

7. 8 Quality Cost and Maintenance Cost

Based on the production practice in a similar medium size manufacturer, which has 5-7% rework rate in the production practice, the quality cost and maintenance cost is assumed to be 10% of total manufacturing cost, since the quality is a significant issue for brake shoes.

Quality and maintenance cost = 0. 1 * (Labor + Utilities + Material) = $187, 481

7. 9 Administration Cost

Based on the estimation of annual production cost, the annual administration cost is estimated by 10% of the total production cost, which is the sum of labor cost, utilities cost, material cost, quality and maintenance cost.

Administration cost = 0. 1 * (labor + utilities + material + quality and maintenance) = $206, 229.

7. 10 Summary

From Table 2, the total cost if Northfork Southern buy the break shoes from outsource is $ 3, 984, 134 per year.

Based on the above analysis, the annual cost for producing coupler knuckles using investment casting process is shown in Table 17.

Table 17. Cost analysis summary

Fixed cost

Total annual cost

Building cost

Machine cost

Labor cost

Utilities cost

Material cost

Quality and maintenance cost

Administration cost

$977, 760

$186, 813

$593, 040

$1, 177, 586

$104, 186

$187, 481

$206, 229

$1, 164, 573

$2, 268, 522

The fixed cost is the investment for this project. Considering a 2-year payback period, if the interest rate is set to be 10% according to the engineering economics practice, the annual worth (A) can be calculated by:

The manufacturing cost per unit is ($671, 015+$2, 268, 522)/ 378, 720=$7. 76, which is lower than the purchasing cost from outsource. That means if the company want to build it and set a 2-year payback period, the annual cost will be lower comparing to buying it.

8. Cost Analysis for New Design in case one

8. 1 New design (based on the report from ME department team)

The idea of new design is shown in Fig. 31.

Fig 31. New design 1 of break shoe

This new design is more efficient in stress analysis as well as has less weight and volume,

Weight of the old brake shoe (With back plate): 2. 7758 kg

Volume of the old brake shoe (With back plate): 1. 159393 x 10-3 m3

Weight of the new brake shoe (With back plate): 2. 7333 Kg

Volume of the new brake shoe (With back plate): 1. 136993 x 10-3 m3

So from this we can say that we have saved around 1. 53% of material by this new brake shoe.

8. 2 Manufacturing process

Based on the proposed design of break shoe, the manufacturing process will not have any change, which means the fixed cost, such as machine cost and building cost will not be changed.

8. 3 Estimated demand for brake shoes in case one:

The fatigue analysis has been run by mechanical engineers by two different cases. In first case they assumed the radius of the brake and wheel is not matching, the inner radius of the brake shoe is 16. 51 inch while outer radius of the wheel is assumed as 19. 51 inch. The life extension for new design comparing to old design is 16. 51%.

Table 18. Demand estimation for case 1

Amount

Unit

Formula

B1. Freight train miles traveled [8]

80 million

miles/year

B2. Total number of freight cars NF operating [8]

94, 660

Cars

B3. Average number of cars each train has

120

Cars

B4. Total number of trains NF operating

789

Trains

B2/B3

B5. Mileage per train operating each year

101, 394

miles/train/year

B1/B4

B6. Mileage between two maintenance

11, 500

Miles

B7. Times of maintenance

8. 82

times/train/year

B5/B6

B8. Number of brake shoes used per train

960

Per year/train

(8)*B3

B9. Total number of brake shoes inspected per year per train

8, 464

shoe/train/year

B7*B8

B10. Percentage being replaced

5%

Brake

B11. Number of brake shoes replaced per year per train

423. 21

shoes/train/year

B9*B10

B12. Plant Size (ANNUAL DEMAND)

333, 912

brake shoe

B11*B4

B13. Plant Size (MONTHLY DEMAND)

27, 826

brake shoe

B12/(12)

Price of one composite brake shoe available in market

$ 10. 52 (approximately)

Cost if buying brake shoes per year

$3, 512, 759. 33

B12* ($10. 52)

The annual demand of composite brake shoes with new design is 333, 912 pieces; while the monthly demand is 27, 826 pieces. The average price for each composite brake shoe is $ 10. 52, which will make a cost of $3, 512, 759. 33 per year for the brake shoes purchasing.

8. 4 Capacity estimation

Since the monthly and annual demand of break shoe’s replacement in Northfolk Southern is changed, based on the capacity estimation in section 3. 2, if the production time is set to be one shift of 8 hours assigned for the production line for 21 working days per month, the demand can be fully filled. The total working day per year is 252 days.

8. 5 Labor cost

Based on the capacity estimation, the production will be run 8 hours per day, which means one shift with 8 hours regular working time. The summary of annual labor payment is shown in Table 19.

Table 19. Labor cost estimation for new design

Labor cost

Common workers (pay by hour)

Skilled workers (pay by hour)

Engineers and supervisors (pay by salary)

Sub total

Total number of labor

6

8

4

Training cost (annual)

$6, 000

$16, 000

$20, 000

$42, 000

Regular Payment

$8. 5

$10. 5

$60, 000

Overtime Payment

$12. 8

$15. 8

N/A

Regular working hours per day

8

8

Overtime working hours per day

0

0

Working days per year

252

252

Annual payment

$102, 816

$169, 344

$240, 000

$512, 160

Total

$554, 160

8. 6 Material cost

Since the material use for the new design 1 will be reduced by 1. 53%, the total material cost will be reduced at the same rate comparing to the previous design, which will be shown in Table 20.

Table 20. Material cost estimation for new design 1

Name of the material

Amount per piece (lb)

Total weights (lb)

Price per pound

Subtotal

Novolak

0. 14

47019

$0. 24

$11, 285

Iron Powder

0. 26

86804

$0. 32

$27, 777

Graphite Powder

0. 24

79570

$0. 45

$36, 168

Asbestos

0. 13

43402

$0. 10

$4, 340

Rubber Flakes

0. 14

47019

$0. 10

$4, 702

Kaolin

0. 17

57869

$0. 11

$6, 181

Total

$90, 454

8. 7 Utilities cost

Since the working time of the plant will be reduced to 252 days a year and 8 hours a day, utilities cost = 0. 0689*(number of machine working hours in a year)*(total power of all machines) = $1, 030, 388.

8. 8 Quality Cost and Maintenance Cost

The estimation of quality and maintenance cost for new design is by 10% of the total of labor utilities and material cost.

Quality and maintenance cost= 0. 1*(labor+utilites+material) =$ 167, 500

8. 9 Administration Cost

Based on the estimation of annual production cost, the annual administration cost is estimated by 10% of the total production cost, which is the sum of labor cost, utilities cost, material cost, quality and maintenance cost.

Administration cost= 0. 1*(labor+utilites+material+qualityandmaintenance) =$184, 250

8. 10 Summary

From Table 11, the total cost if Northfork Southern buy the knuckles from outsource is $3, 512, 759 per year.

Based on the above analysis, the annual cost for producing coupler knuckles using investment casting process is shown in Table 21.

Table 21. Cost analysis summary for new design 1

Fixed cost

Total annual cost

Building cost

Machine cost

Labor cost

Utilities cost

Material cost

Quality and maintenance cost

Administration cost

$977, 760

$186, 813

$554, 160

$1, 030, 388

$90, 454

$167, 500

$184, 250

$1, 164, 573

$2, 026, 752

The fixed cost is the investment for this project. Considering a 2-year payback period, if the interest rate is set to be 10% according to the engineering economics practice, the annual worth (A) can be calculated by:

The manufacturing cost per unit is ($671, 015+$2, 026, 752)/ 333, 912=$8. 07, which is slightly bigger than the unit annual cost for the previous design.

9. Cost Analysis for new design in case two:

9. 1 New design case two (based on the report from ME department team):

For the second case, in which the brake shoe perfectly fits over the wheel, our new design proves much better than the original design. Maximum equivalent stress in Original model (in composite part) is 25. 02Mpa, while new model has the maximum equivalent stress of 19. 22 Map, which is 23. 18% reduction in maximum stress. Even this stress in new model is distributed stress rather than the concentrated stress. Now fatigue life of the original model is 6465 cycles, while new improved brake shoe has total 13703 cycle of life span, which is improvement of 111%.

9. 2 Manufacturing process

Based on the proposed design of break shoe, the manufacturing process will not have any change, which means the fixed cost, such as machine cost and building cost will not be changed.

9. 3 Estimated demand for brake shoes for Norfolk Southern Railways

Table 22. Demand estimation for case two

Amount

Unit

Formula

B1. Freight train miles traveled [8]

80 million

miles/year