Production Scheduling Improvements in an Automotive Sector Company

Govind Sharan Dangayach, Himanshu Bhatt

***Abstract*—**The paper attempts to overcome the fluctuations occurring in demand of the components in an automotive sector company. Resource and time being the strict constraints, the production is not able to match the pace of the fluctuating demand. So, we introduce some production schedules that help in meeting out the required demand. The merits and demerits of the approaches are also highlighted.

***Keywords*—**Production scheduling, Demand rise, Capacity constrained resource (CCR), Overtime.

I. Introduction

PRODUCTION scheduling, the problem of sequentially configuring a plant to meet its forecasted demands, is a crucial problem throughout the manufacturing industry. The necessity of maintaining product inventories in the face of unpredictable demand and stochastic factory output makes scheduling models [1].

According to [2], monthly revenues are restricted by labor and production capacity, and may be negative to reflect a lost opportunity, when one system type is down for a changeover, while other system types are able to respond to the changeover more quickly. This loss in opportunity cost is specifically included to help differentiate the systems during changeovers. Operating costs include fixed and variable costs for the months the system is in production and only fixed costs for the months a system is in changeover. Labor costs include any overtime costs if necessary to meet production goals.

A bottleneck resource is one whose capacity is equal to or less than the demand placed on it, whereas a non-bottleneck is the one whose capacity is greater than the demand placed on it.

A capacity constrained resource (CCR) is a resource that, if not properly scheduled and managed, is likely to prevent the product flow to deviate from the planned flow. A bottle neck can be a CCR, but so could a non-bottleneck if not properly scheduled. The performance of the system depends a lot upon the CCR [3].

Overtime is the upper time spent on any work. It is sometimes preferred so to minimize the fluctuations occurring in demand.

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II. Literature Review

Eliyahu Goldratt initialized and presented his ideas on production scheduling with the development of a proprietary computer black-box software program known as optimized production technique (OPT). It was for sale to the companies but with no information about the theory or methodology of OPT, while with the promise was that the schedules developed would take capacity into consideration and would make more efficient use of capacity-constrained resources to maximize the throughput [3].

In 1984, Goldratt and Cox published a novel, *The Goal* that outlined some of the concepts underlying OPT [4]. After two years Goldratt and Cox published novel, *The Race* that further explored and explained the concepts underlying OPT [5].

Umble and Srikanth gave a thorough look at these concepts, then known as synchronous manufacturing, in 1990, and claimed that the term was coined in 1984 at General Motors. With more widespread understanding, synchronous manufacturing concepts have been adopted by many more companies [6].

Goldratt refined his idea into, now known as the theory of constraints, an expansion of his original OPT concepts. Since then, he made the concepts more widely known through seminars and publications etc [7].

III. Problem Description

The case (automotive) company manufactures various automobile engine parts such as crankshaft assembly, engine block, rocker arm etc respectively. Due to a sudden rise in the demand of the Crankshaft assembly, the plant is not able to meet out the demand for the same, within the existing resources. The production of the crankshaft isn't the same as per the demand i.e. the company is able to meet out around 95% of the demand. The rest goes as an opportunity loss. Profit that could be earned from 5% production is not earned. So meeting out the demand is one of the objectives of the thesis. The company produces Crankshaft assembly in 4 similar crank shaft lines as shown in the Fig. 1.

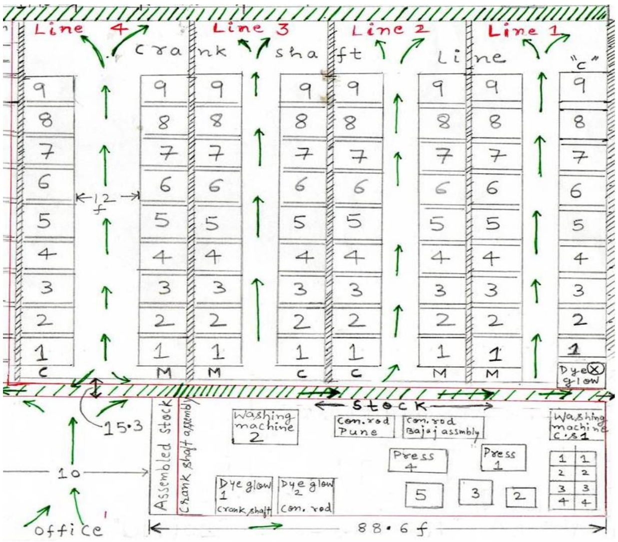

Fig. 1 Crankshaft assembly line

The production in the company runs for 25 days in three respective shifts (7 hours 15 minutes i.e. 26100 seconds) in a month due to off on Sundays (4 Sunday) and a tentative holiday on an average. There are 4 lines for the production of crankshaft assembly in which 4 different crankshafts models are produced i.e. W, X, Y and Z. The demand for model W and X is high, for Y is moderate and for Z is quite low. So, the following Table I shows the number of days operated by various lines in a month.

TABLE I
WORK SCHEDULE OF THE CRANKSHAFT LINES

S.No.	Line /Model	No. of days operated in a month
1	Line 1/ model W	25
2	Line 2/ model X	25
3	Line 3/ model Y	20
4	Line 4/ model Z	15

Now, Demand from each line/shift = 550 components;
So, Demand from each line/day = 1650 components;
& Production from each line/shift = 450 components;
So, Production from each line/day = 1350 components;

B. Reason for the Loss

The reason for this loss is due to a bottle neck present in all 4 lines i.e. IDG (Internal diameter grinding) machine which is not able to match/operate with the pace of the rest of the machines in the line. There is a pair of IDG machines in each line.

The following Table II shows the cycle times of various machines of a crankshaft assembly line:

TABLE II
CYCLE TIMES OF THE MACHINES IN THE CRANKSHAFT ASSEMBLY LINE (LH)

S. No.	Machines	Cycle time/component(processing time+ loading/unloading time)+ transport time between machines (seconds)	Maximum Production/Line/Day in number of components
1.	SFC	40	652
2.	RT	45	580
3.	FT	44	593
4.	VMC	42	621
5.	DAM	30	870
6.	TR	22	1186
7.	IH	39	670
8.	ODG	43	607
9.	IDG	57	458
10.	DYE GLOW	22	593
11.	WASHING MACHINE	10	652
12.	ASSEMBLY	23	567

So going through the data, we observe that the cycle time of IDG machine is quite more as compared to the other machines. The production capacity of each machine in the line is greater than 550, except IDG. So, the IDG machine is a bottleneck and CCR here, who's scheduling is to be managed well.

On an average basis, taking the production from the IDG machine to be 450 components/ shift. Hence, no. of components of crankshaft assembly produced in any of the line is also equal to 450.

C. Production Requirement & Solution to Meet the Demand

Here, we find out the difference between the demand and the production of the crankshaft components in a month.

1. Production & Demand Patterns for the Lines

Four different lines produce four different models of crankshaft assemblies. Now, we will see the amount of production and demand for various lines/models separately.

1. Line 1/Model W- the production in this line runs for 25 days in a month due to high demand for this model.
   Daily Demand = 550*3 = 1650 components;
   So, Monthly demand = 1650*25 = 41250 components;
   Daily Production = 450*3 = 1350 components;
   So, Monthly Production = 1350*25 = 33750 components;
   Difference between amount demanded & amount produced = 41250-33750 = 7500 components;
2. Line 2/Model X- the production in this line runs for 25 days in a month due to high demand for this model.
   Daily Demand = 550*3 = 1650 components;
   So, Monthly demand = 1650*25 = 41250 components;
   Daily Production = 450*3 = 1350 components;
   So, Monthly Production = 1350*25 = 33750 components;
   Difference between amount demanded & amount produced = 41250-33750 = 7500 components;
3. Line 3/Model Y- the production in this line runs for 20 days in a month due to moderate demand for this model.
   Daily Demand = 550*3 = 1650 components;

So, Monthly demand = 1650*20 = 33000 components;
Daily Production = 450*3 = 1350 components;
So, Monthly Production = 1350*0 = 27000 components;
Difference between amount demanded & amount produced = 33000-27000 = 6000 components;

4. Line 4/Model Z- the production in this line runs for 15 days in a month due to low demand for this model.
Daily Demand = 550*3 = 1650 components;
So, Monthly demand = 1650*15 = 24750 components;
Daily Production = 450*3 = 1350 components;
So, Monthly Production = 1350*15 = 20250 components;
Difference between amount demanded & amount produced = 24750-20250 = 4500 components;
The following Table III shows the difference between the demand and the production of the components for a month.

TABLE III
DIFFERENCE BETWEEN THE DEMAND AND PRODUCTION OF THE COMPONENTS PER MONTH

S. No.	Line /Model	Monthly Demand (25 days)	Production	Difference
1	Line 1/ model	41250	33750	7500
2	Line 2/ model	41250	33750	7500
3	Line 3/ model	33000	27000	6000
4	Line 4/ model	24750	20250	4500
	TOTAL	140250	114750	25500

Hence we see that the 25500 more components should be produced to meet the demand and earn better profits. This difference is basically due to the high cycle time of IDG machine making it a bottleneck.

2. Initial Step –Production Schedule for Meeting the Demand

To increase the total monthly production, the IDG machines of Line 3 & Line 4 can be utilized for the days for which these lines were idle. Line '3' has 5 days of idle period whereas Line '4' has 10 days of idle period. So, during this period the IDG machines of the respective lines are also idle. So, just by changing a little programming/codes for these IDG machines, any model (W, X, Y or Z) can be produced with same rate of production, configuration and quality. Now, we will calculate the production increased due to this approach.

Number of components an IDG can produce per day = 1350;

Number of idle days, in which production can be done on the IDG machines for meeting out the demand = Idle days for IDG Line 3 + Idle days for IDG Line 4 = 5+10 = 15 days;

Number of components IDG can produce in 15 days = 1350*15 = 20250 components;

The company was short with 25500 components earlier. Now utilizing the idle IDG machines of line 3 & 4, 20250 components are produced.

Hence we are left with (25500-20250 = 5250) 5250 components more.

Now meeting the demand is the goal here. 5250 more components or more must be produced to meet the demand. This is the objective of the paper.

As we observe from the data's that the IDG machine can maximum produce a quantity of 458 components per shift per line. So nothing much can be done with the IDG machines regarding increasing its capacity, with the same resource.

IV. SOLUTION APPROACH

So to solve this problem, there are two ways/approaches:

A. *Increasing the bottleneck resource*
B. *Over time approach*

A. Increasing Bottleneck Resource

This approach deals with buying an additional bottleneck machine (pair) for the existing system, so as to increase the capacity and fulfill the demand. We observe that the company needs to produce 5250 more components per month in order to meet out its demand.

So to meet out the demand and reach the capacity of each IDG > 550 per shift, we can purchase additional IDG machines (pair of IDG machines i.e. for LH and RH component) to cover up for all of the 4 lines.

The bottleneck machine can produce around 1350 components per day in three respective shifts, and the requirement of the company is for (5250/25) 210 more components over a day. So, this approach is feasible & may sound to be beneficial for the company.

1. Payback Period Estimation

Buying the new IDG machine would cost an amount which would have a certain amount of payback period. So, calculating the Payback time period of the new machine and justifying the option of buying the machine.

Opportunity loss of 5250 components implies a certain amount of profit loss to the company. Assuming the profit to be Rs. 100 per component, we can calculate the total loss incurred by the company per month.

Profit/component = Rs. 100

Monthly Profit (if an IDG is installed) = 5250*100= Rs. 525000

Price of an IDG machine/LH or RH = 75 lacs (data as per given by the management)

So, Price of pair of IDG machines (LH and RH) = 75*2 = 150 lacs

Payback of an IDG in months = Price of machine/Daily profit earned = 15000000/525000 = 28.57 months or 2 years, 4 months and 16 days.

But, if the machine runs for the payback period time (28.57 months), then there would be some other costs also associated with it like running cost of machine (electricity), labour cost, maintenance cost etc.

2. Associated Cost Estimation

Components can be made by an IDG machine in a shift =

450;

So number of shifts required to produce 5250 components = 5250/450 = 11.66 shifts every month;

(i) Labor cost:

The cost of wages paid to workers during an accounting period on daily, weekly, monthly, or job basis, plus pay roll and related taxes and benefits (if any).

Labor cost/shift/person= 360

Number of labors required for producing a crankshaft assembly would be 2 (one at LH machine and another at RH machine respectively)

So labor cost for 28.57 months on the new IDG machines = 360*11.66*28.57*2 = Rs. 119883.44

(ii) Electricity cost:

It includes the electricity cost that is incurred in running the machine for a month. So electricity cost per month can be calculated as = Fixed/demand charge per month + Energy charge = Fixed/demand charge per month + Energy charge = 45696 + 55795.904 = 101491.90; (refer to appendix).

(iii) Maintenance cost:

It includes all sorts of breakdowns, preventive maintenance cost (oiling, coolant etc), tool wear etc. The maintenance cost per IDG machine per month varies from Rs. 5000 to Rs. 7000. So, taking Maintenance cost of IDG machines = Rs. 6000 per IDG machine per month.

Maintenance cost for payback period = 6000*28.57 = Rs. 171420

Total cost related with the new machine for the Payback time = Cost of the machine + Labor cost + Electricity cost + Maintenance cost.

Total cost = 15000000 + 119883.44 + 101491.90 + 171420 = Rs. 15392795

So the Modified final pay back (months) = Total cost/profit made per month= 15392795/525000 = 29.31 months.

B. Overtime Approach

1. Analysis and Applicability of the Approach

The company works in three shifts every day except on Sunday's and a few gazette holidays. Consulting with the management, it was found that the company runs for around 25 days per month on an average. 5 days can be assumed to be off day including 4 Sunday's and assuming an average holiday.

As already discussed, the company should produce around 5250 more parts per month or 210 components per day to meet the demand of its crankshaft assembly. So going for overtime could be an effective approach. Analyzing the concept of overtime along with the perspective of cost incurred in that would help us to understand its suitability and feasibility for implementation to this case. With the assumption that the number of the resources (IDG machines) is to be kept the same i.e. 4, we apply the overtime approach.

As we calculated earlier that we require 11.66 (5250/450) shifts production per month, to meet out the total monthly demand.

Number of IDG machines = 4;

Number of shifts in a day = 3;

So total number of shifts that can be run on 4 IDG machines simultaneously = 4*3 = 12;

Number of parts produced in the above calculated 12 shifts = 450*12 = 5400;

The component produced by the overtime of 1 day i.e. 5400 is greater than the components needed further to meet out the demand (5250).

So finally we observe that just in around 1 day of overtime on any Sunday's of the month, the demand for the whole month can be met easily.

So, overtime approach is feasible & can be preferred on any off day or Sunday every month to balance the production loss & meet out the demand.

2. Overtime Cost Estimation

To analyze and implement this approach, first we need to watch out the merits and de-merits of the approach. So, calculating the Cost incurred in overtime.

Salary of a labor per 25 days per shift = Rs. 9000

Labor cost per shift= 9000/25= Rs. 360/shift,

Number of labors required for 11.66 shifts on 8 IDG machines (LH and RH) in 4 respective lines = 93.28

Except where overtime hours are to be accumulated under an overtime agreement, all overtime hours must be paid at the rate of at least one and half times (1.5x) the employee' regular wage rate.

But overtime the money given = 1.5* (Salary given on normal working days)

Overtime money paid i.e. labor cost on overtime per shift = 360*1.5 = Rs.540

So, total labor cost for the required number of labors = 93.28*540 = Rs. 50371.20

3. Associated Costs Estimation

Overtime in the plant or machine not only considers labor cost, but some other costs are also associated with it. Those associated cost includes Machine running cost (electricity consumption), Maintenance cost etc.

(i) Electricity cost (Running cost):

It includes the electricity cost that is incurred in running the machine for a month. So electricity cost per month can be calculated as = Fixed/demand charge per month + Energy charge = (1600 +1954.34) *2 = 7108.68; (refer to appendix).

(ii) Maintenance cost:

It includes all sorts of breakdowns, preventive maintenance cost (oiling, coolant etc), tool wear etc. The maintenance cost per IDG machine per month varies from Rs. 5000 to Rs. 7000. So, taking Maintenance cost of IDG machines = Rs. 6000 per IDG machine per month.

Hence, the maintenance cost for IDG pair of machines = 12000

So, Total cost incurred in the overtime for meeting out the demand is given by;

Total cost = 50371.20 + 7108.68 + 12000 = Rs. 69479.88

Money lost otherwise = Components not produced* profit/component = 5250*100= Rs. 525000

As money lost >> total overtime cost, so this approach is feasible and can yield profitable results.

V. Results and Discussion

A. Increasing the Bottleneck Resource

As the time of payback of the new bottleneck machine (around 2.5 years) is pretty satisfactory, so the approach of adding a resource (Machinery) sounds to be quite effective. As a result of which, a new resource (IDG) can be bought for the company to meet out the demand & increase profit.

The loss of 5250 components per month can be met now and even more parts can be processed at the same machine. This approach has an additional benefit i.e. in case of further rise in demand over future, this system will respond well to the demand rise up to a certain level depending upon the capacities of the machines of the line.

B. Overtime Approach

As we can see that the cost spent on overtime is a lot less than the profit earned per month. Just by spending Rs. 69479.88 on over time, a profit of amount Rs. 525000 can be made. The ratio of profit to money spent comes out to be 7.55. The merit of this approach is that in just one day of overtime; the demand for crankshaft assembly component can be met and making a lot of profit. This approach can be also suitable for the high and low demand fluctuations. As we are utilizing just one day in here to meet out the demand, similarly 4 five times more the components can be produced as are produced in one day here utilizing the 4 more off days in a month. But this would be the case in which demand is very high. So this is a versatile approach. But at the same time this approach depends a lot on the will of labors to work on off days. It needs cooperation from the labor side. Occupational health research demonstrates that overtime work may be associated with health problems. Also, overtime impacts on labors fatigue, stress, injuries, tiredness etc, so additional workers or workers on lease can be hired for this purpose.

From this analysis, we observe that overtime is also an efficient & effective approach to meet out the any variation in demand.

VI. Conclusion

In meeting out the demand for the crankshaft components, it is observed that the first approach provides a versatile solution to the problem with a payback of around 2.5 years whereas the latter approach reveals that just by spending 69479.88 on over time, a profit of amount Rs. 525000 can be made per month simultaneously meeting out the demand and saving 86.7% of the money per month. The overtime approach has high marginal profits, so even labors from outside can be hired in order to reduce the working pressures on the existing workers. So both the approaches yield profitable and versatile results while overcoming with the fluctuations in demand.

Appendix

The Company works above a load factor of 50%. According to the terms of the provisions of section 45 of the Electricity Act, 2003, the following chart in Fig, 2 shows the tariffs and charges for different categories of consumers approved by the Uttarakhand Electricity Regulatory Commission and effective from 01-04-2012.

Rate Schedule		Descriptions	Fixed / Demand Charges (Per Month)	Energy Charges
RTS-5: Government Irrigation System	1.	Upto 75 kW	Rs. 25/kW	Rs 3.95/ KWH
	2.	Above 75 kW	Rs. 25/kVA	Rs 3.80/KVAH
RTS-6: Public Water Works	1.	Public Water Works	Rs. 25/kW	Rs 3.80/KVAH
RTS-7: LT&HT Industry	1.	LT Industries (upto 25 kW)	Rs. 90/kW	Rs 3.60/KWH
	2.	LT Industries (above 25kW & upto 75 kW)	Rs. 90/kW	Rs 3.25/KVAH
	3.	HT Industries (above 75 KW/88KVA & upto 1000 KVA)		
	3.1	Load factor upto 33%	Rs. 200/kVA	Rs. 2.85/kVAH
	3.2	Load factor above 33% & upto 50%	Rs. 200/kVA	Rs. 3.10/kVAH
	3.3	Load factor above 50%	Rs. 200/kVA	Rs. 3.40/kVAH
	4.	HT Industries (above 1000 KVA)		
	4.1	Load factor upto 33%	Rs. 260/kVA	Rs. 2.85/kVAH
	4.2	Load factor above 33% & upto 50%	Rs. 260/kVA	Rs. 3.10/kVAH
	4.3	Load factor above 50%	Rs. 260/kVA	Rs. 3.40/kVAH

Fig. 2 Electricity tariffs and charges for different categories of consumers

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