Development of Cost Effective Production Improvements within an engineering production environment

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Abstract

Specdrum Ltd specialise in the manufacture of pulleys for heavy plant conveyors for the quarry and mining industry. At peak periods of production within the factory, customer demands outweighed output rates within the production line. A range of methodology was applied to the current factory setup and procedures in an attempt to ensure the maximum production rate was being achieved. In this scenario the bottleneck process- welding, was targeted for improvement with the view to enhance the overall output rate. A range of potential technologies and solutions were investigated and trialled where possible. After deliberation and an analysis of results a final cost effective method was trialled over a twelve week period of time with benefits clearly visible from the results obtained.

Keywords: pulley, manufacturing, machining, optimization, welding

Introduction

Specdrum Ltd is an SME that has manufactured conveyor end pulleys for over thirty years, currently they supply customers worldwide with pulleys. The make-up of a pulley is relatively simple as displayed within the exploded view in Figure 1. Steel pipe is cut to length and two end plates are welded to the inside of both ends, a shaft is then attached to the plates either through a weld or an optional locking device as displayed.

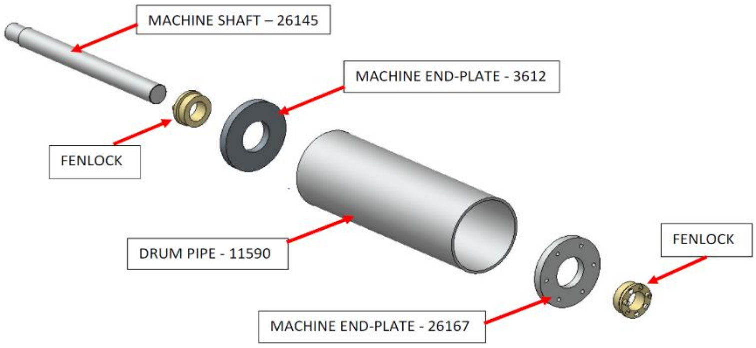


Figure 1 Assembly procedure for pulley manufacture

Given the simple nature of production processes involved, efficiency is a crucial factor in ensuring improvements in production output levels within the factory. This is further emphasised when the small batch sizes and bespoke nature of each pulley is taken into consideration. Emphasis on improving the processes is what will ensure maximum output.

Smaller organizations are becoming increasingly proactive in improving their business operations through implementation of lean methodology. [Matt, 2013] One thing that is to be considered throughout this process is costs, the tendency for companies of this size is to fear that implementing lean manufacturing is going to be costly and time consuming. [Matt, 2013] This will eat into production time and therefore profits.

The alternative view to this is that period of improvement can improve competitiveness through faster innovation and production, increasing flexibility and reducing costs across the board. [Matt, 2013] The fact that the production process is at the core of the organisation means that any improvements created will pass on to the various other areas of the organisation. With SMEs, being at the core of an economies dynamics support funding should be easily compiled if required. [Abel-Koch, 2015]

In essence if production rates increase, there is enhanced capacity for sales which in turn will increase the profitability of the organisation and encourage for growth into the future.

Internally it was accepted that before major technological changes were made it was important to firstly utilise the system which was currently in place within the factory to ensure the organisation is working at its actual capacity. This would avoid a tendency to overlook small and simple changes which could make significant differences.

The aim of this project did not concentrate solely on any particular methodology but rather on finding the most suitable methodology for increasing production rates. The aim is to be as cost effective as possible, finding a solution which delivers as much improvements for as small a price as possible. However if significant investment can be justified this will be taken into consideration as well.

Procedure

Before any actions could be taken a range of information and data was required on which to base judgement and decide on which particular areas to target. The first plan was to follow five typical pulleys through production and time each process. Taking an average of the times should allow for the areas that are inhibiting production to be targeted for improvements. The value stream map of the results is displayed in below.

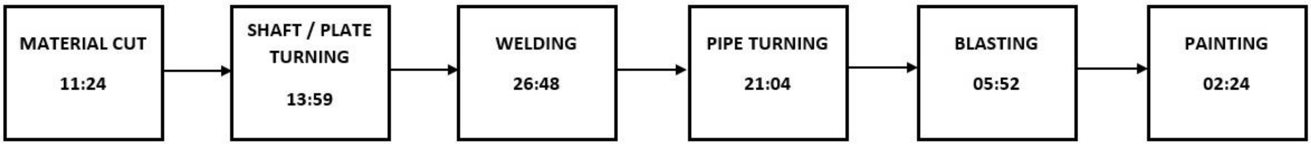


Figure 2 Pulley Production Process Value Stream Map

Although this is the solely the timing of each individual procedure involved in pulley manufacture and overlooks a lot of factors within the production process, it does clearly highlight the areas which require improvements.

It is clear to see that both welding and the turning of the pipe are the most time consuming stages of production and the rest can cope with this level of production at ease. With welding being the main contributor in terms of time to production and the scope for improvement it was chosen as the main area for improvement. It is essential to be aware that the bottleneck changes over time in a lot of processes when changes are made. [Stevenson, 2011]

Grade	Size	Qty of Pulleys	%
A	8"-10"	1369	30%
B	10"	1310	29%
C	12"	882	19%
D	14"-16"	692	15%
E	16"+	320	7%
	Total	4573	

Figure 3 Pulley size breakdown

To get a clearer picture of the situation regarding the welding process investigation over an extended period of time was required in order to identify the key areas of concern. To do this each weld was given a sheet on which they recorded each pulley that they welded in a day. This would give all the information regarding quantity and size of the pulleys that were being welded on a daily basis and whether there were many discrepancies from welder to welder regarding performance.

In order to fully gauge exactly what pulleys were being manufactured by each welder a full breakdown of pulleys that have passed through production was examined. This was based upon pulley diameter as it is the crucial dimension in weld application for the end plate to the pipe.

The large number of different pulleys means a time could not be determined for each individual pulley. With this information a grading system for pulleys could be determined this is displayed in figure 3. This grading system would be used to monitor welding performance. Each welded pulley would be categorised into one section and this would be totalled up to determine how many of each grade could be welded in a day, this would act as a tracker for the welding process. This would be the basis on which the results would be judged. It would display whether the changes have made any positive effect on the process.

Following this gathering of information there was an examination of areas in which the welding process could be improved. Two areas of concern that were chosen to be addressed was the layout of the welding areas and the jigs currently be used for welding.

Some of the main areas of concern was the layout of each welding area and the range of jigs being used for welding. Each area ranged in dimensions and layout. The image below displays some of these issues. The welding area is clearly untidy with no clear layout or structure. Application of lean methodology would be required to refine the layout of each welding area.

The CAD images in figure 4 display the plans for the welding areas. Each area will follow the same format and be of uniform size. This new layout leaves welders with the bare essentials to complete the task. Anything that is not required on a regular basis is removed and can be collected from the supervisor.

The aim of this is to aid with the streamlining of the process. Less time should be spent searching for tools/material within the welding areas, material flow should improve and general cleanliness should be enhanced creating a better working environment.

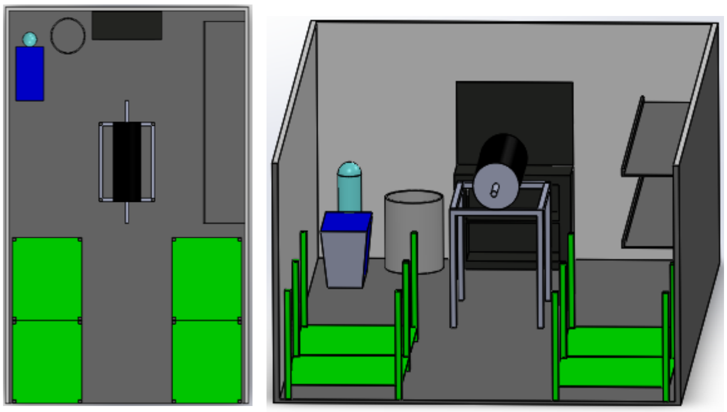


Figure 4 CAD model displaying planned improvements to Welding Area

The range of jigs being used was also a cause for concern. Some welders use jigs which allow for welds to be applied while a pulley is vertical whilst others used jigs on which the pulley sits horizontally. This creates variance from welder to welder in terms of quality and consistency.

To create a uniform welding jig/ method allows for a lot of scope. There are numerous options in terms of robotic and semi-automatic welding options that would likely increase output by a significant percentage. A number of suppliers were contacted regarding such solutions.

It was then decided to put forward three potential solutions;

1. A fully robotic welding solution
2. A semi-automatic welding solution
3. An in house manufactured jig

Each of these were to be trialled as far as was logically acceptable until it became clear whether it was a feasible option or not. The aim at this stage would be to produce a uniform layout and improvement of the welding technology that would significantly increase the output being measured through the welding tracking system which was put in place.

Results

The results of the three potential welding solutions is displayed below;

1. **Robotic Welder**

The model displayed below in figure 5 was sent to us by a supplier in England. When welding is being completed by the robotic arm at one side of the machine, another drum would be tacked up for welding on the other side.

This automated system would still require two operators, one tacking and preparing the pulley whilst the other operates the robot. These processes take up a large portion of the time spent upon each drum in the welding process. Coupling this factor along with the cost of £85,000 to £120,000 depending on various suppliers and fixtures used this would be viewed as substantially above our budget level for such a project.

It was viewed that although the machine may reduce the welding time for each drum this time will not be significant enough to justify the level of investment that will be required to implement. It was decided this was as far as a full robotic method would be taken at this point.

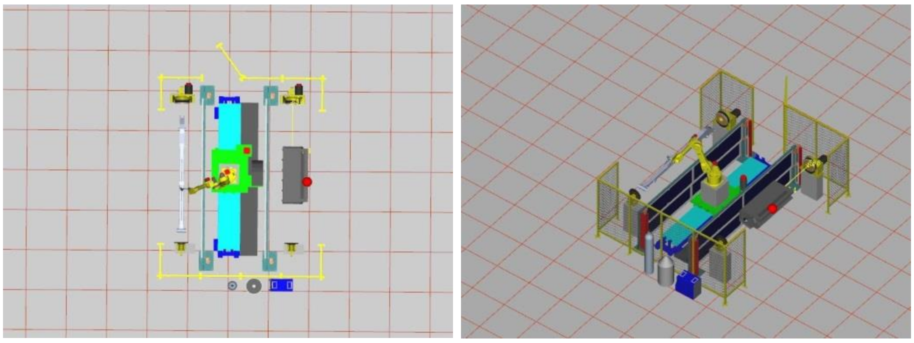


Figure 5 CAD layout of automated robotic welding machine

2. **Semi-Automatic Option**

A full trial was set up to determine whether a semi-automated welding technology provided by Javac welding automation was capable of welding a range of ready tacked pulleys in a more efficient process and quicker time than the current manual process. This was well within budget coming at a cost of £8,200. Displayed below is the welding technology which was to be tested.

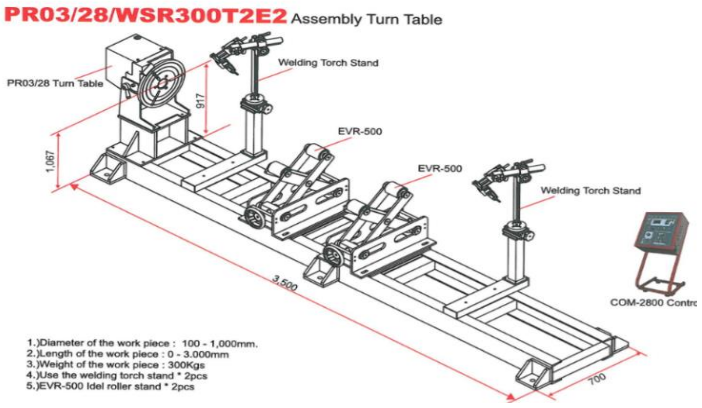


Figure 6 Semi automated welding assembly turn table

The results of the trial were not as positive as was predicted. It was not possible to complete a full rotation of welding on any of the pulleys provided for the trial. This was due to a number of issues; there was restricted access for the welding iron at the chuck end. This occurred due to the shortness in the protruding shaft from the chuck. This would mean on pulleys with little protruding shaft there is little chance of welding both sides at the one time.

The tack size was a lot bigger than the weld depth being created by the operating welder. Therefore when the welder reached the tack it jammed and stalled while the welding wire was still being fed out causing a blob of splatter to build up which would stall the process entirely whilst the blob had to be grinded down. It was impossible to keep an eye on both ends of the pulley whilst things like this was occurring.

These inhibiting factors could only be overcome through technological enhancement which would have significantly increased the cost and defeated the benefits of the machine therefore after the trial it was left that semi automation would not be further examined.

Figure 7 Images of semi-automated trial

3. Internally Manufactured Welding Jig

A simple jig was designed and manufactured internally to be trialled over a prolonged period of time. The design is displayed in figure 8 below. The pulley is placed upon the rollers and the welder uses a foot pedal to power a low speed motor which turns the pulley and allows the weld to be applied.

Figure 8 internally manufactured welding jig

This jig allows the welder to solely concentrate on applying the weld to pulleys without also have to turn the pulley with one hand. Speed should therefore be more consistent, in turn this should lead to a more consistent quality of weld.

The cheap tailor made option solved a lot of the issues and as can be seen in figure 9 was more than capable of dealing with larger pulleys. Performance of the jig was not to high enough standard to instantly commit to application of it across the board permanently and the restructuring of the welding cells around this design. However it was successful enough to justify an extended trial period to determine the effects it will have upon welding performance within the factory.

Figure 9 Welding jig in action

This was planned for a six month period in which the earlier mentioned tracking system would be implemented to display any improvements as a result of the new jig and the cleaning of the welding areas (figure 10 below) combined.

The difference made to the welding areas is highlighted in the before and after photos below. There is a clear difference in the uniform nature and structure of the areas. Tool boards have been installed to reduce missing tools and encourage a culture of "a place for everything and everything in its place" on the manufacturing floor.

Figure 10 Welding Area Before and After Lean Application

The actual size of the welding bays reduced by 1.5m through this process as the amount of space being wasted on unnecessary material was reduced. From the welders point of view a brighter tidier working environment was created that was hoped would enhance productivity.

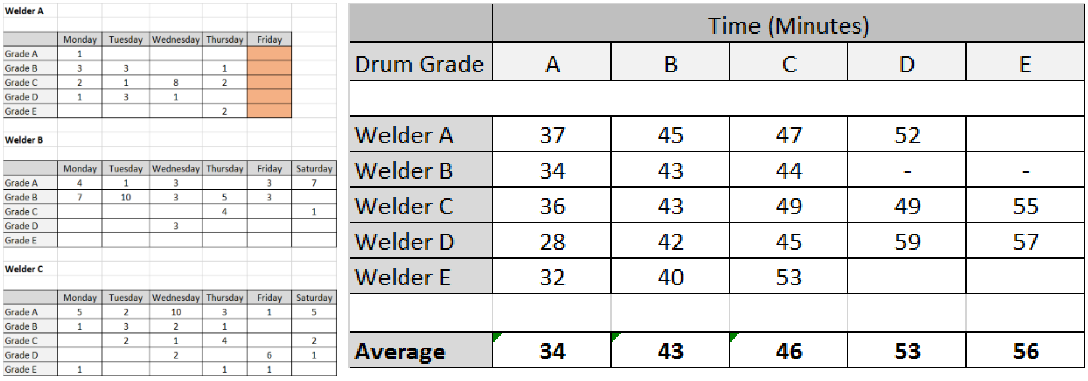
Welder Performance Results

Welding performance was monitored from 8 weeks prior to changes and then again over 8 weeks following the changes to the welding areas being made. The results of these changes are displayed in the range of graphs below.

Figure 11 Graphs displaying Welding Rates Before (left) and after (right) changes were made. Top two graphs display individual welder performance, bottom two display collective performance.

The graphs display how the changes created an instant U-turn in production rates over a short period of time. Pulleys welded turned from being below 140 per week to climbing above 200 in a week, this is a 30% increase within 8 weeks. The individual welding performance displays the effect absenteeism has upon production. There is clear correlation between absences and poor output rates.

It is clear that the changes have made a positive effect that is still increasing over time. The welding log is displayed below in figure 12, it corresponded with the pulley grading system developed earlier in the project. This allowed for accurate manufacture times to be compiled based on the figures gathered from each welder's performance over a prolonged period of time.



Welder A

	Monday	Tuesday	Wednesday	Thursday	Friday
Grade A	1				🟧
Grade B	3	3		1	🟧
Grade C	2	1	8	2	🟧
Grade D	1	3	1		🟧
Grade E				2	🟧

Welder B

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Grade A	4	1	3		3	7
Grade B	7	10	3	5	3	
Grade C				4		1
Grade D			3			
Grade E						

Welder C

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Grade A	5	2	10	3	1	5
Grade B	1	3	2	1		
Grade C		2	1	4		2
Grade D			2		6	1
Grade E	1			1	1	

	Time (Minutes)				
Drum Grade	A	B	C	D	E
Welder A	37	45	47	52	
Welder B	34	43	44	-	-
Welder C	36	43	49	49	55
Welder D	28	42	45	59	57
Welder E	32	40	53		
Average	**34**	**43**	**46**	**53**	**56**

Figure 12 Welding Log and Corresponding Manufacture Times

These results display the improvements made through the changes that were made to the welding process, on top of this it is also clear that there is now a better control on production and data which can aid the removal of this particular bottleneck.

Discussion

The changes made coupled with the application of lean methodology has undoubtedly improved the situation regarding the welding process. Whereas before the project began there was little or no data available regarding processes and times, now there is an ever growing range of live data relevant to performance.

A capacity can now be determined for production rates within pulley manufacture and work can be accurately be delegated to welders with figures to back up the level of work decided upon. On top of this a better control on overtime is now also possible from a management point of view.

The implementation of the lean methodology to the welding areas and the jig performance has improved work conditions for the welders greatly. Each welder is now solely concentrated on the application of the weld which should greatly improve quality.

In terms of the welding jig performance to date has proved successful and small issues surrounding it has now been eradicated. These improvements coupled with the figures generated and welder feedback will instil enough confidence to justify an improved, higher quality jig being rolled out across the production line.

The aim at the beginning was to improve the welding process in a cost effective manner and this has been achieved. More expensive options were shunned in favour of more effective measures at lower costs. The costs accumulated was minimal with the standardising of the areas coupled with the manufacture of news jigs not even reaching four figures. This is in stark contrast to the earlier costs quoted for robotic machinery.

It became clear very early in the project that robotics was not going to suit the application and developing a tailor made option ourselves was the best placed option to take production to the next level in the shortest period of time. The low cost meant that investment was ready immediately.

This attitude has led to instant improvements which were required to ensure customer requests were met. The value of this in an overall sense will only become evident over time.

Conclusion

The project was a success over a short period of time, increasing production rates through the welding process which should also improve other areas such as quality (enhanced emphasis on weld) and profit margins (overtime reductions).

What was discovered in the search for improvements is that it is more important to find the best fitting to the organisation rather than the most impressive level of improvement. It is vital to deliver as much improvement to justify a price tag. In this project it is clear that this was achieved.

The targeted bottleneck is now being reduced at ever improving rates over time. Improvements like those on display here increase innovation within the factory and encourage similar improvements to be made, changing culture of an organisation over time.

The theory applied here through the targeting of this process will set a precedent to further improve other areas of the production process as well. What may be found is that over time, a system may not only have one primary bottleneck, but also secondary and tertiary bottlenecks. [Roser, 2002] The methodology developed here will be applicable across processes and over time should lead to significant improvements across the factory.

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