Enhancing the competitiveness of an SMME in the Automotive Industry through the introduction of laser based manufacturing. A case study.

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Abstract
The Automotive Industry uses large volumes of woven synthetic cloth in their paint shops. The cloth is used to clean the car bodies prior to painting. A basic requirement for this application is that the cloth is lint free to avoid blemishes in the paintwork resulting from adherent lint. The cloth is produced in large rolls and has to be cut to size before it is used. It is of paramount importance that the cutting process does not compromise the lint free quality of the cloth. Traditional mechanical cutting methods can not retain the lint free character of the cloth primarily because of fraying of the cut edges.

Laser cutting is a thermal process where the cut is produced by melting and vaporisation of material. Where laser cutting is applied to synthetic fibre the cut is produced by melting the individual fibres resulting in a semi sealed cut edge that is totally free of fraying and lint.

This paper illustrates how the introduction of laser cutting into the manufacturing process not only solved the lint problem but also improved the quality of the product as well as the productivity and profitability of the company.

Introduction

Since the invention of the laser in 1960, laser technology has found applications in virtually all spheres of human activity. Today lasers are found in fields as diverse as medicine, telecommunication, manufacturing, engineering and entertainment to name but a few. The strategic importance of laser technology was realised as early at the 1980's when it was identified as a key technology for maintaining global competitiveness. This realization prompted large scale investment in programmes aimed at the development and implementation of all aspects related to laser technology. During the last two decades of the previous century, practically every industrialised country conducted a government sponsored laser technology advancement programme. Notable examples include:

EUREKA-EUROLASER
Industrial partners and research institutes from 24 countries were involved in this programme.

Laser Research and Laser Technology (1987-1992) and LASER 2000 (1993- 1997)
These two programmes were funded by the German Ministry for Research and Technology. Over a period of 10 years some 537 million DM were spent to position Germany as a global leader in laser technology and was largely responsible for the leadership position in the file of laser technology that Germany currently enjoys.

Precision Laser Machining Programme.
This programme was aimed at enhancing the global competitiveness of the USA industry through the development of high speed laser machine tools. Defence related

technologies were transferred to a consortium of industrial partners at a cost of USD32.9 million. It was partly funded through the White House Technology Reinvestment Project.

Today laser technology is firmly entrenched as a driver of competitiveness and prosperity in the industries of successful countries like Germany, the USA and Japan.

The importance of laser technology in manufacturing.

In a manufacturing context a laser is essentially a device that produces a high intensity light beam that can be focussed to very small spot sizes on the surface of a work piece. Spot sizes are typically of the order of 0.2 mm in diameter and with laser powers of up to several kilowatt readily available, power densities in excess of 1 million watt per square centimetre can be generated on the surface of a work piece. This highly localised heat input is the basis of laser materials processing and in particular laser cutting.

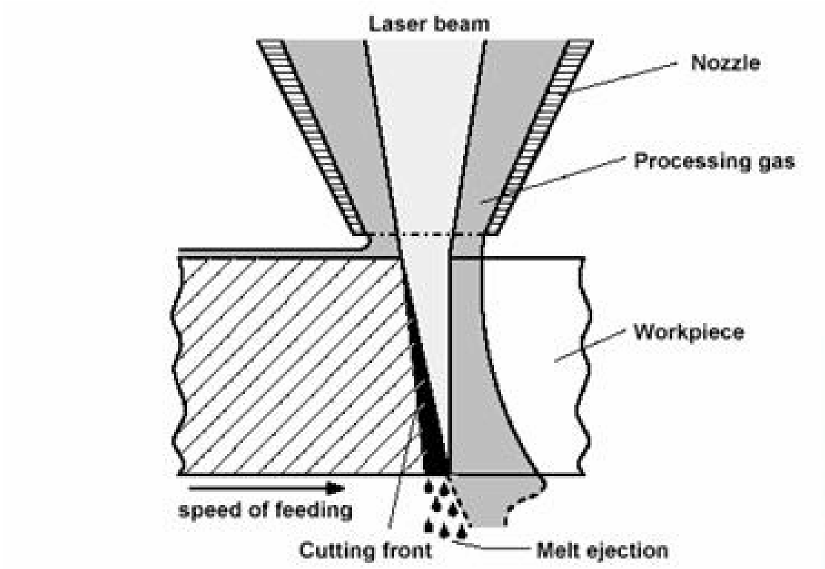


Figure 1 Diagram of the laser cutting process.

The importance of laser technology in a manufacturing environment results form the ability to combine high productivity and high quality with a high degree of flexibility.

Factors that contribute towards the high levels of productivity are:

- Speed – Laser processing is often faster than competing technologies.
- Reliability – It is non contact machining which eliminates tool wear and tool breakage. Jigs and fixtures are greatly simplified. Laser machining is now a mature technology where system uptime of 95% and higher is an industry norm.
- Ease of automation - Laser machining is essentially a CAD-CAM process which is readily integrated into automated production systems.
- Low scrap rates - This is typical of a CNC process.
- Fast set-up – Changeover from one product to another often requires no change in tooling.

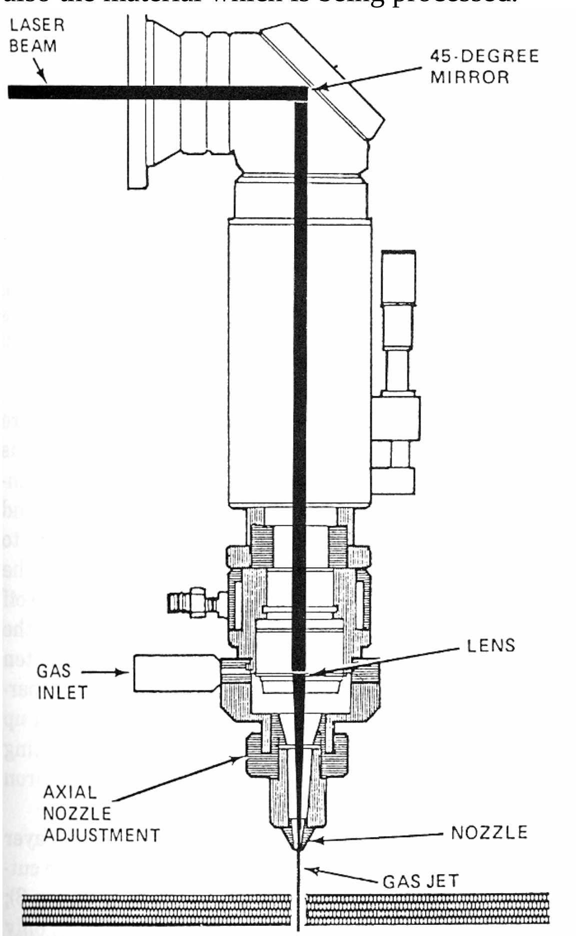
Quality

- Accuracy – In general accuracies are typical of a CNC process but extreme accuracies are possible where the focusability of laser light is fully exploited.
- Reproducibility

Flexibility

- Design changes are affected fast and easily.
- The same laser machining system can often be used to process a range of different materials.
- The same laser system can often be used to perform different processes such as cutting, welding and hardening with only minor changes.

In addition the generic advantages listed above laser processing also offers additional and often unique advantages which depend on the specific process and sometimes also the material which is being processed.



Source: J. Powell et al., *1988 Industrial Laser Annual Handbook*, p. 56.

Figure 2 Typical geometry of the focusing module used for laser cutting

Laser based manufacturing in the South African SMME environment.
While laser technology is certainly not a solution to all manufacturing problems, it has the potential to produce decisive competitive advantages provided that its advantages are optimized and well matched to the envisaged application. In addition there are significant entrance barriers against the successful implementation of laser technology on the shop floor:

- Cost – Laser based machining systems are generally accepted as capital intensive compared to competing technologies. In South Africa the situation is further aggravated by the fact that equipment is fully imported from overseas.
- Specification of required equipment – Since laser equipment is expensive it is important not to over specify equipment. At the same time it is even more important that the specification will not only meet current requirements but also anticipated future needs.
- Lack of decision support - The technology is different from traditional manufacturing methods and is generally speaking not well understood. Potential suppliers are geographically removed from end users. Even if OEM's have representatives in South Africa, equipment is seldom kept in stock and demonstrations can only be given overseas at their principals. Different suppliers will offer different performance features and it is important to pose the right questions and criteria in order to arrive at an objective comparison.
- Lack of local support – Successful implementation depends on readily available local support specifically as far as maintenance is concerned. Although laser equipment is inherently reliable malfunctions do occur. Trouble shooting from remote locations is difficult and due to the specialised nature of the equipment malfunctions will invariably require the attention of a service engineer. If a service engineer has to be dispatched from abroad it may result in unacceptable delays in the production schedule of the local user.

  Support should also include assistance with the development of new and non standard applications. This is particularly important for first time laser users. Most OEM's run applications laboratories for this purpose.

While all potential users of laser based manufacturing equipment need to take proper cognisance of these factors, it stands to reason that because of their often limited resources, SMME's are particularly vulnerable. Yet, in order to remain competitive in a global economy it is essential that local SMME's should not only have access to state of the art technology, but should also be able to implement it successfully.

The National Laser Centre (NLC) at the CSIR is mandated to introduce and promote the implementation of laser technology in South Africa. The Laser Materials Processing Group (LMP) within the NLC in particular, is tasked with the introduction of laser based manufacturing processes into the South African manufacturing industry. In view of the importance of the SMME sector as a driver of growth and employment and a realization of the problems that this sector faces as far as the acquisition of appropriate and sustainable laser technology is concerned, the NLC has positioned itself to address the entrance barriers referred to in the earlier paragraphs. The NLC offers a service that is based on well equipped applications laboratories and supported by 20 years experience in laser materials processing. The service consists of the following elements:

- Technology awareness programmes– Laser technology is still relatively unknown in large sectors of the South African manufacturing industry and many misconceptions still persist. The NLC promotes the understanding of laser technology, its advantages and disadvantages compared to competing technologies and potential applications through popular articles in trade magazines, presentations to industry societies, customer visits and demonstrations at its own facilities.
- Feasibility studies – Potential applications are evaluated on behalf of prospective laser users. Where appropriate customers are also informed of alternative technologies which are more cost effective.
- Process development – Where successful applications have been identified process parameters are optimised in order to arrive at a solution that best suits the customer's requirements.
- Specification of equipment – Based on the identified process parameters a generic specification is compiled. This will typically include the required laser power and performance specifications for the beam delivery system and materials handling equipment.
- Decision support – A list of potential suppliers is supplied to the client. Advice is given on the specification of appropriate test pieces to be produced by the supplier in order to demonstrate the equipments capacity for satisfying the client's requirements.
- Supply of equipment – In special cases where off the shelf equipment is not available for a particular application the NLC has the capacity to develop and construct purpose built systems.
- Ongoing support – Support is given on the development of new applications and processes which are compatible with existing equipment. In the case of NLC supplied equipment support will also include maintenance.
- Production support – In instances where successful applications have been identified but required volumes do not justify the acquisition of equipment, the NLC may consider making its facilities available for the required production. This could also serve as an interim measure while the market potential is assessed or being developed. The NLC will base the decision of whether to render production support on the availability of capacity. In the case of NLC supplied equipment, production support can also be rendered while equipment malfunctions are being rectified.

An example of how this model functions in practice is provided by the following case study:

TAPPO Industries.

Company profile

Tappo Industries supplies the Major Motor Vehicle Manufacturers, Allied Suppliers and paint shops with various lint free cloths, anti static lint free garments, heavy duty protective covers and tool bags. The company was established 14 years ago and is currently situated in the Automotive Supplier Park in Rosslyn where it occupies modern premises and employs a work force consisting of 50 women.

Industry profile.
The automotive industry is known for its highly competitive nature and for the emphasis on quality and reliability. These factors are equally important to the suppliers of products and services to the automotive industry. The quality of products and the reliability of the supply of these products are crucial to the success of a company which wishes to operate in this industry.

Product profile
A major focus of the company's business is to supply solvent wipes to automotive paint shops. These wipes are used to clean car bodies prior to being painted to ensure a high integrity blemish free coat of paint. Two types of wipes are used. The first one is used to remove excess sealant from the car body where weld seams have been sealed. The second type is used as general body cleaner. In both instances it is critically important that the cloth is absolutely lint free. Specially produced lint free knits from 100% polyester are used for the production of the wipes. Four knits are used which differ in texture and density. The raw material is supplied in rolls of 1.5 meter in width. The material has to be cut into squares of 400 x 400 mm before it is supplied to the end users. It is all important that the cutting process should not compromise the lint free character of the raw material.

Production technology
Originally the wipes were manually cut with either a rotary blade or a jig saw. In order to eliminate the possibility of lint being produced in this process the wipes were cut oversized and then overlocked around the edges. Afterwards the individual wipes were shaken out to ensure that all lint was removed. This process was time consuming, used extra material and it was difficult to ensure that quality standards were maintained. When large volumes of wipes are produced in this way it is obvious that the work force is subjected to high levels of repetitive activity with low levels of stimulation.

An improvement to the production process was implemented when a hot knife trim replaced the overlocked edges. The wipes were still cut oversized and then manually trimmed round the edges by placing the wipe on a glass surface and then moving a hot knife along a straight edge that was place parallel to the edge of the wipe.

In 2000 Tappo Industries was requested by their customer base to conform to international standards as far as the quality of their wipes was concerned. A fact finding mission was sent to Europe where the BMW plant in Germany was visited. Although samples of the wipes used at BMW could be obtained no information on the production methods or equipment would be supplied. Tappo Industries did however manage to establish that laser cutting was used. It is well known that laser cutting of synthetic fabrics often yielded the added advantage of producing a sealed edge.

The company was now faced with the problem of sourcing a laser cutting system that would satisfy their needs. It was soon realised that commercially available laser cutting systems were vastly overspecified for Tappo Industries' requirements. Laser cutting systems are designed for profile cutting where high demands are put on the speed and accuracy with which complex contours can be executed. This requires rigid constructions, high accuracy mechanical components, sophisticated motion control systems and elaborate CAD/CAM software all of which were irrelevant to Tappo Industries' needs and added unnecessary costs. The vast majority of laser cutting systems are also aimed at sheet metal cutting and are fitted with high power kilowatt level laser sources. Textile cutting is normally performed with laser powers of the order of a few hundred watts. Tappo Industries came to the conclusion that a laser system ideally suited to their needs was not commercially available. All the available options would incur unnecessary costs which would jeopardise the financial viability of the project.

The development of a purpose built solution

When it became clear that a suitable laser cutting system was not commercially available Tappo Industries approached the National Laser Centre for assistance. The following steps followed:

- Need assessment.

The need assessment took the following factors into consideration:

- ➢ Required production rate.
- ➢ Shape and size of wipes top be produced
- ➢ Number of different fabrics that needed to be cut

From the first two factors the required cut speed could be estimated. Time lost through loading of raw material onto the cutting system and unloading of cut product should also be estimated and taken into consideration when estimating the cut speed needed to meet the required production rate.

- Feasibility study

Once the required cut speed had been determined trial cuts were conducted on the laser cutting facilities at the national Laser Centre. The main purpose of the trials was to establish the level of laser power that would be required to cut all the different fabrics at the required speed. The laser source is a major contributor to the overall cost of a laser system and it is important that the available laser power is not too high while at the same time allows a sufficiently large operating window. A second objective was to confirm that the required cut edge quality could be produced.

- System design

A conceptual design was compiled where the following elements were considered:

- ➢ Laser source

Low power carbon dioxide lasers are the most cost effective way to process non metals including fabrics. The infrared wavelength of 10.6 micron is well absorbed by non metals. In addition it does not constitute an eye safety hazard unlike most other laser types.

It was decided to utilise an NLC designed and manufactured CO2 laser rather than an imported unit. This decision was primarily based on the need to ensure maximum system availability. With an in-house designed laser 24 hour maintenance support could be guaranteed. Imported units can't be repaired locally and have to be shipped back overseas to the suppliers for maintenance.

- Cutting table
    - Cutting table size

In order to minimize the loading and offloading time it is advantageous to have a large cutting area. However the larger the cutting table, the higher the demands on the rigidity and stability of the support structures for the beam delivery system become if the requirement for accurate beam alignment is to be maintained. Another factor which had to be taken into consideration in determining the size of the cutting tabled was that it had been decided to implement a manual loading and offloading system. Operators had to be able to reach the entire work area.

It is customary to enclose laser cutting tables, primarily for safety reasons. An enclosure protects operators from hazards associated with beam reflections, moving NC equipment as well as potentially hazardous decomposition products produced as a result of the cutting process. With proper design and adequate safe operating procedures the need for a protective enclosure can be eliminated resulting in a cost saving as well as a reduction in the time required to load and unload the system.

- Cutting table surface

The main purpose of the cutting table surface is to support the fabric in the focal plane of the laser beam while it is being cut. At the same time contact between the fabric and the table surface should be minimized because the cutting process produces decomposed fabric which should be allowed to escape through the bottom of the cut. If the vapour is not allowed to escape, it recondences to form a blemish on the cut edge. It is equally important that the surface should not reflect laser light since reflected light will damage the cut product.
The optimum solution was found to be a grid of anodized aluminium slats.

- Loading/offloading system

It was decided to put the rolls of raw material onto a roller cradle placed at the one end of the table. Loading would be performed by two operators each holding one corner of the fabric, pulling it off the roll and over the table surface. Cut product would also be collected by hand.

- Extraction system

The dissociation products generated by laser cutting are potentially hazardous and need to be captured effectively to protect operators. In the absence of an enclosure a combination of both top and bottom extraction was implemented.

- Linear motion system

Since the primary objective with the system is straight line speed rather than contouring accuracy it was decided to use belt driven linear stages powered by stepper motors. This is a much more cost effective solution than the combination of precision ball screws, linear bearings and servo motor systems that are commonly encountered on laser cutting systems.

- Beam delivery system

It was decided to configure the beam delivery system in the form of a gantry based “flying optics” system. It is customary to adopt this configuration with large work areas.

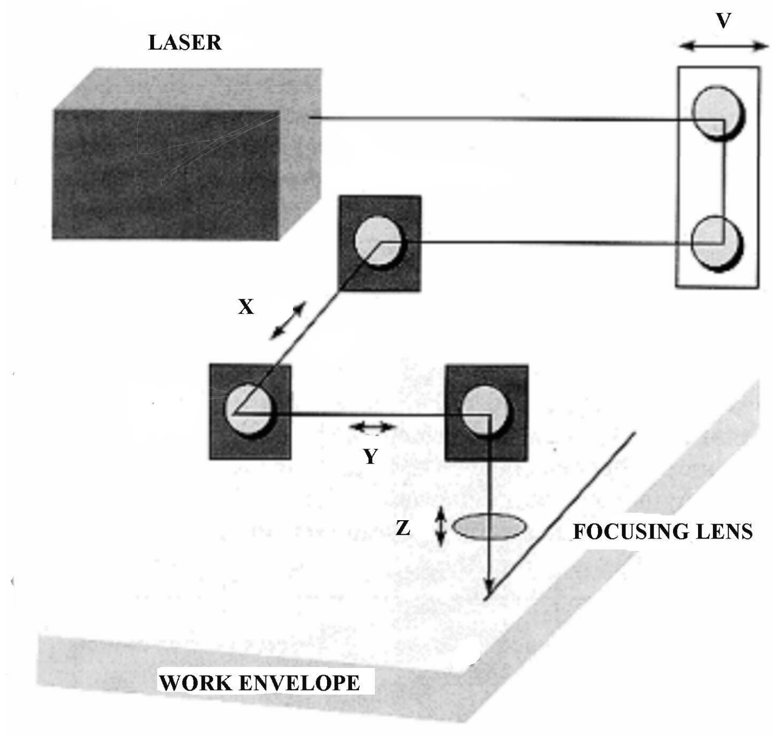


Figure 3 Diagram of "flying optics" beam delivery.

- Assist gas system

A co-axial assist gas jet is delivered with the focussed laser beam to the fabric during the cutting process. The function of the assist gas is to assist with the removal of decomposed material, to protect the focusing lens from contamination by decomposed material and to prevent combustion of the flammable fabric. Normally an inert gas such as nitrogen is used. To save cost it was decided to use compressed air. A compressor was integrated into the system for this purpose.

- Programming software

Since only a well defined range of products was to be cut on the system it was decided not to equip it with a comprehensive CAD/CAM system. Instead the required CNC programs were generated offline on behalf of the customer.

The conceptual design was translated into manufacturing and assembling drawings.

- Procurement and construction

  The entire system was constructed at the NLC.

- Testing
  The system was extensively tested to ensure reliability and compliance with the performance specifications.
- Installation and commissioning.
  The NLC produced ProCut laser cutting system was commissioned and installed in January 2001. To date it has completed 11 000 hours of operation.

Figure 4 ProCut Laser cutting system at Tappo Industries

Figure 5: Cut product ready to be offloaded.

The benefits derived from the introduction of laser based manufacturing.

- Increased capacity

It is estimated that the introduction of laser cutting technology has trebled the solvent wipe output capacity of the company.

- Improved quality

The lint free quality of the wipes can now be guaranteed with confidence.

- Improved customer confidence

In addition to the guaranteed quality the security of supply has also greatly benefited from the increased production capacity. It is now possible to build up stocks which was previously not possible and was of great concern to Tappo Industries' customers.

- Improved working conditions for employees

The manual cutting technology employed 8 people in a context characterized by a high degree of tedious repetitive work. Only 4 people are required to operate the laser cutting system. The remaining employees were redeployed as seamstresses thus acquiring a much improved work environment as well as an additional skill.

- Expansion of product range

The increased prosperity of the company allowed it to expand its range of products and services. In some instances this is directly as a consequence of the availability of the laser cutting capability. For example the laser system is also used to produce parts for overcoats which are used in clean room environments.

Conclusion

From the preceding case study it is evident that the introduction of laser based manufacturing can have a profound effect on the competitiveness and profitability of SMME's. In the case of Tappo Industries the benefits alluded to in the previous section enabled the company to entrench themselves as a preferred supplier in a highly competitive market. It is however important that effective measures are put in place to assist SMME's in overcoming the entrance barriers encountered in the acquisition of high technology solutions. These measures should include all the levels of support mentioned in this paper.