International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

Moving Horizon Model Based Control in the Presence of Feedback Noise

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Abstract: This paper studies the performance of networked control systems with a receding horizon controller. It is also assumed that there exists exogenous noise signal in feedback channel, modeled as a stochastic process. The impact of this noise on the closed-loop system performance is examined through both theoretical analysis and numerical experiments. An adaptive compensator is proposed to assist the original receding horizon controller. The performance of this solution is verified through simulation.

Keywords: Model predictive control, networked control system, noise, tracking

1. INTRODUCTION

With the advance of communication technology, the concept of networked control system is becoming more and more popular both in academia and industry. When a traditional feedback control system is closed with a communication channel (for example, wireless network), which may be shared with other nodes besides the control system, then the control system is termed as a networked control system (NCS). A typical networked control system has four basic components: sensors, controllers, actuators and communication channel. Networked control system has many advantages over traditional control systems, for examples, it enabled the execution of several tasks from long distance; the complexity and maintenance cost of the system is potentially lower because of elimination of unnecessary wiring; upgrading or modifying components becomes relatively easy and low-cost. However, these advantages do not come for free. There are also technical challenges that come with the networked control system, which gave rise to important research topics.

It is well known that when sensors and actuators communicate with a remote controller over a possibly noisy communication network, estimation as well as controller design becomes challenging [1]. For example, stability of the closed loop requires additional conditions on the communication channel used. In [3, 4, 5, 8], it is pointed out that the capacity of communication channel in the feedback loop should be lower-bounded to guarantee closed-loop stability. [6, 9, 10, 13, 14] studied the performance limitation of control system and related it to the information content in the feedback channel. Various coding schemes for networked control are studied under different channel assumptions [2, 11]. Event-triggered control is also proposed [7, 12, 15, 16, 17] which can save transmission bandwidth while maintaining closed-loop stability.

In this paper we are interested in the performance of a networked receding horizon controller, also known as model predictive control. It is assumed that there exists exogenous noise signal in feedback channel which corrupts the measurement. In this study package drop, delay and quantization effects are ignored to avoid unnecessary complexity. This setup is very realistic since model predictive control is widely used in industrial applications, noisy signals in communication network is also quite common. We studied this scenario with both theoretical analysis and numerical experiment, an adaptive compensator is also proposed to improve the performance of the original receding horizon controller.

The rest part of the paper is organized as follows: in section 2 the problem formulation is presented. Section 3 describes the modified MPC algorithm with adaptive compensator, experiment results are in section 4 while section 5 summarizes this study.

2. PROBLEM FORMULATION

2.1 Model predictive control over communication channel

Model predictive control refers to a class of control algorithms that rely on an explicit plant model to predict its future response. At each control interval an MPC algorithm attempts to optimize future plant behavior by computing a sequence of future control variable adjustments. The first input in the optimal sequence is then sent to the actuators, and the entire calculation is repeated at the next time intervals. Originally developed to meet the specialized control needs of power plants and petroleum refineries, MPC technology are now very popular in a wide variety of application areas including chemicals, automotive, and aerospace applications [18,19,20].

Figure.1 shows a closed-loop system with model predictive control and noisy feedback channel over the network. We consider the case when the plant is linear, the equation that describe the system dynamics is:

$$x(t+1) = Ax(t) + Bu(t) \quad (1)$$

Assume that the noise that corrupts the state measurement is i.i.d. Gaussian, denoted as $w(t)$, the model predictive control problem can be formulated as

$$\min_u \sum_{k=t}^{t+N} J(x(k), u(k)) \quad (2)$$

$$g_i\big(x(k), u(k)\big) \geq 0, i = 1,2 \ldots m \quad (3)$$

$$x(k+1) = Ax(k) + Bu(k), k = t+1, \ldots t+N\text{-}1,$$
$$x(t) = x^* \quad (4)$$

$$G(s) = \frac{458}{s^3+31s^2+259s+229} \quad (5)$$

Here x^* is the noisy state measurement at time t.

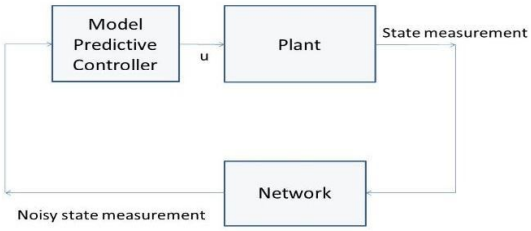

Figure.1 Model predictive control over noisy communication network.

2.2 Effect of exogenous noise on performance

The noise in the feedback channel has a negative impact on the performance of closed-loop system. With the noise $w(t)$, the initial state x^* at time t is no longer accurate. Optimization based on this inaccurate initial state may lead to sub-optimal control sequences in the following time steps. This sub-optimal control gives rise to deterioration of closed-loop performance.

3. MODIFIED MPC ALGORITHM

In this section we propose a modification of the original model predictive control framework. This is achieved by adding an adaptive compensator to the original design, as depicted in Figure 2. Note that there is no noisy feedback channel in this figure. This compensator is actually an adaptive controller that helps the model predictive controller by adaptively correcting the state error in the measurement.

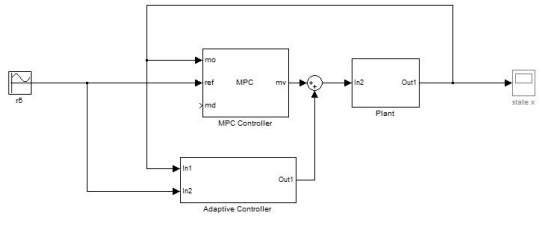

Figure. 2 Modified model predictive control with adaptive compensator

The adaptive controller takes both the reference signal and measured noisy state as input, with a high-gain adaptive law, it can track the state changes and generate a proper control action that adds to the control action of the MPC controller to compensate the effect of measurement noise. In the next section we use experiments to show the effectiveness of the proposed approach.

Some theoretical analysis needed.

4. SIMULATION

In this section we use a simple example to illustrate the modified model predictive control approach we proposed. For a linear time invariant dynamical system with transfer function

we consider a tracking task where the objective is to make the output of the dynamical system track a given sinusoidal reference signal $r(t) = \sin\left(\frac{\pi}{5}t\right)$. The output $y(t)$ is also measured and sent to a model predictive controller through noise-corrupted communication channel. The noise is modeled as i.i.d. Gaussian with zero mean and variance value 5.

The model predictive controller has a sampling period of 0.1 second. We chose a prediction horizon of 60 steps and a control horizon of 1 step. Quadratic functions are used as objective function of the resulting optimization problem:

$$J(x,u) = \sum_{t=1}^{60}((y(t)-r(t))^T Q(y(t)-r(t)) + u(t)^T Ru(t)) \quad (6)$$

Here $y(t)$ and $r(t)$ are the output and the sinusoidal reference signal, respectively. We implemented this control solution using MPC toolbox from MATLAB. Our proposed modified MPC is also implemented with a carefully tuned adaptive control block. Here we made the assumption that the initial condition of the controlled plant is known to the adaptive controller.

The performance of these two control solutions are compared in Figure.3. It can be observed that the output of modified MPC is much better.

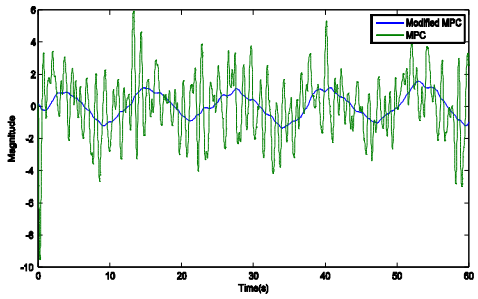

Figure 3. Comparing the tracking performance of traditional MPC and proposed modified MPC

We also test the two control solutions with a square wave reference input. With large noise in the feedback channel, regular MPC cannot track the steps very well. Using the proposed modified MPC the tracking performance is much better, as depicted in Figure 4 and Figure 5, respectively.

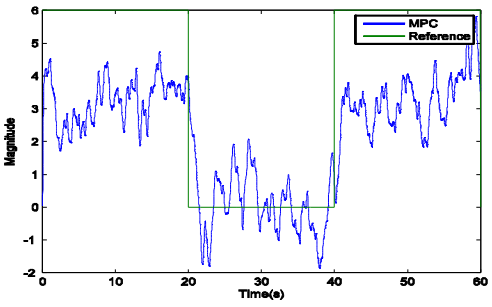

Figure 4.Tracking performance of regular MPC with square wave as reference input.

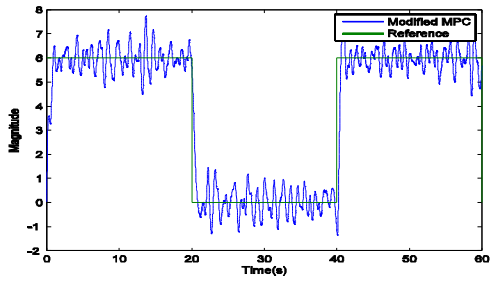

Figure 5.Tracking performance of proposed MPC with square wave as reference input.

5. CONCLUSION

In this paper we studied the receding horizon model based control (MPC) when the state measurements are obtained through noisy communication channel. A modified MPC controller is proposed which use an extra adaptive controller to compensate for the exogenous noise. Experiment results show that the proposed method outperforms regular MPC solution in typical output tracking application.

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International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

Development of Automated Glass Frosting Machine

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Abstract: As Industry is turning more and more to computer-based automation; very complicated and precise components having some special requirements are demanded by these industries. The demand is also increasing for glass industry; they are still produced on handicraft scale essentially involving manual labor. To avoid child labor and the manual process of sandblasting is very hazardous and creates dust, therefore there is need to automate the Glass frosting technique, so we are proposing the Automated Glass frosting machine. Glass frosting is one of the etching methods of imprinting images on glass. Glass frosting involves creating a design on a glass surface by applying an acidic or abrasive substance. In a proposed concept the glass is stationary and sand is filled in nozzle and sand blasting will be done with the help of nozzle and the nozzle will move accordingly to carve a stencil on glass. With the help of Solid works the assembly is made and interfacing is done by using the KIEL software and flash magic.

Keywords: Glass etching, Sandblasting, Acid etching, and Chemical etching.

1.INTRODUCTION

With the pressing need for increased productivity and delivery of end products of uniform Quality, industry is turning more and more to computer-based automation. At the present time, most of industrial automated manufacturing is carried out by special purpose machines, designed to perform specific functions in a manufacturing process. The conventional methods, in spite of recent advancements are inadequate to machine such materials from stand point of accuracy, precision and economic production. At the present time, most of industrial automated manufacturing is carried out by special purpose machines, designed to perform specific functions in a manufacturing process.

Glass Frosting is an age-old old method of imprinting images on glass**.** There are three ways to create a piece of etched the glass.

1. Acid-etching
2. Chemical-etching
3. Sand-blasting

1.1.1 Acid etching:

Acid etching uses an acid resistant material to cover areas of the glass that the artist wants protected. Hydrofluoric acid is then applied to the glass to produce the design.

1.1.2 Chemical etching:

Chemical etching is another way to produce etched glass and is normally what is found in glass etching kits. Just as in sandblasting, a stencil is used to protect the glass where the etching effect is not desired. Instead of an abrasive, however, a chemical cream is applied to the glass.

Acid etching can create the same appearance as sandblasted glass**.** One of the major advantages of acid etching over sand blasting is that it can be done simply and without as many tools. A frosting effect can also be achieved using different strengths of acid etching compounds.

1.1.3 Sandblasting

Sandblasting, also known as abrasive blasting is a process by which small particles of sand or another hard crystalline material are "blasted" through a small funnel or hose using pressurized water or air. The process is commonly used to strip away old paint, to remove rust, to clean stone buildings or to decorate glass. The manual activity of etching process could be subjective and highly dependent on the experience of workers. So glass etching techniques are being increasingly used to save the time.

Sand blasting is an old technique. It was and is used for a wide variety of purposes like tombstone engraving, paint or corrosion removal, house facades cleaning, and surface roughening for better adhesion, device demarking, and glass decoration and (live) tooth drilling. Since the Second World War, sand blasting is used to

systematically investigate the erosion resistance of materials. This field of research was important for e.g. gas turbines and pipelines and has grown very large. This provides us with a large amount of knowledge on equipment and particle-target interaction. The development of flat panel displays in the nineties caused sand blasting to be developed to an accurate machining method.

Sandblasting allows for greater variation through the use of different degrees of coarseness in sand, and also for depth blasting, giving the finished product a rich textured appearance. Sand blasting is a very interesting technology; the sandblasting **glass etching** process consists of corroding glass by violently projecting sand upon its surface by means of a current of air or steam. The tube conveying the current of air or steam terminates at a nozzle containing a series of fine holes. The sand is thrown violently against the glass plate or any other body placed within its range, and thus exerts a corroding action. By varying the quantity of the sand, the volume and velocity of the current, as well as the diameter of the jet, the desired effects are obtained.

2. LITERATURE SURVEY

1.The manual activity of etching process could be subjective and highly dependent on the experience of workers. So glass etching techniques are being increasingly used to save the time.

2. Sand blasting is an old technique. It was and is used for a wide variety of purposes like tombstone engraving, paint or corrosion removal, house facades cleaning, and surface roughening for better adhesion, device demarking, and glass decoration and (live) tooth drilling. Powder blasting is very interesting technology for the realization of 3 dimensional microstructures in brittle materials like glass or silicon. In this paper detail basics of oblique powder blasting techniques process, by varying the angle the angle of powder beam & using mathematical procedure it will able to separate the erosion effects of primary impacting particles & will create new options for 3 dimensional micro fabrication of brittle materials. [1, 2]

1. From the above paper [1]; realize with its complex 3-dimensional & monolithic suspended microstructures in glass. Comparison has been done with metal contact mask & alternative is found photosensitive flex polymer. [3]

2. The general information on particle target interaction and powder blasting conditions are explained. Also discusses some of these mask types. The surface roughness created by powder blasting is much higher compared to other micromachining methods. Therefore this thesis shows how the roughness is created and how it can be manipulated. To further decrease the minimum feature size, the average particle size also has to be decreased. However, the removal rate drops sharply if the particles become too small, a detailed description of this transition, the typical channel profiles that are created by powder blasting are discussed. Effects can be reduced by changing the particle size or the jet impact. [4]

3. Abrasive particles are propelled by an inert gas of velocity. When directed at a work piece, resulting erosion can be used for cutting, drilling, etching & polishing. The paper testing & analyze various process parameters of abrasive jet machining is explained in detail. [5]

4. Mechanism of AJM, how AJM works, study of process parameters are explained in detail. Various observations have been seen and from the observation what range should we select for process is explained. As Nozzle Tip Distance increases, the Top surface diameter and Bottom surface diameter increases. As the Pressure increases Material Removal Rate (MRR) also increases. [6]

5. Steel bridges are vulnerable to corrosion and their surfaces and the process is hazardous to health, so an automatic robotic system would be an alternative. A hexagonal topology based coverage pattern is adopted to reduce unblast areas & editing process is included to confine blasted areas within boundaries and is verified by simulations based on an industrial robot arm. [7]

6. The erosion rate is PMMA was measured with stream of 25 μm Al_2O_3; the erosion rate was at 25^o. The effect of mask particle interactions was observed. Large discrepancies were seen between the model and the experimental results. [8]

7. The paper describes an algorithm to model a sandblasted glass based on “fog-based height maps”. Sand blasted glass is used as a base (canvas) & the medium of coloring is crayons. The stylized glass paintings generated by algorithm are better suited for non-photorealistic; this paper proposes a new technique of glass painting with different support medium and coloring medium. This paper provides new directions for computer generated glass paintings. [9]

8. In the development of automation controllers the trend has been to move towards soft controllers so as to provide better control, more flexibility and more reliability with intelligent diagnostics of machine faults. So industries have gradually moved from conventional relay logic control to programmable logic control and then to computerized numeric control. The detail study about P.L.C is explained in this paper. [10]

9. Various ways of fabricating channels in silicon are discussed. The various types of silicon etching are explained in this paper. [11]

10. The present paper is an experimental study regarding the influence of abrasive quantity on surface quality generated when low pressures of water jet abrasive cutting are used. [12]

3. PURPOSE OF SANDBLASTING:

3.1Significance

Sandblasting was originally used to sharpen and grind tools. Wood, metal, glass, concrete and brick are some of the substrates that are usable in this process. It will remove any dirt, paint or other substance in preparing the substrate for painting. Sandblasting also refreshes the look of concrete and brick. Sandblast old sidewalks, brick walls, windows and even roofing. Sandblasting can also smooth rough surfaces.

3.2 Techniques

There are two types of sandblasting techniques. Wet sandblasting is commonly used for exterior jobs, and dry sandblasting is typically used on interior jobs or special projects. The wet sandblasting process works well to remove paint, stucco and other debris from a substrate.

3.3 Considerations

Some cities and towns require a permit for sandblasting. Wet sandblasting is preferable over dry sandblasting as it is less invasive. Before sandblasting, cover structures not needing the process with plastic sheeting to protect them from erosion.

4. PROBLEM IDENTIFICATION:

The following problem occurs during glass etching process:

4.1 Incomplete Reaction with Glass

The etching chemical may fail to react properly on the glass if the surface has any traces of grime, dust or residue prior to application. You must remove all potential barriers from the glass using water. Avoid using a glass cleaner, as it may leave a film behind. Dry the glass thoroughly after cleaning and avoid putting fingerprints on the etching surface by wearing gloves.

4.2 Skin Irritation

The chemicals in the etching substance can burn and irritate the skin.

4.3Damage to Sink Enamel

Over time, rinsing your etching projects off over an enamel or porcelain sink may take its toll on the luster of the basin, especially if you use generous amounts of etching cream or use the product regularly.

5. AIM AND OBJECTIVE

Due to the rapid changes in the manufacturing environment, there has become a growing need for computer based systems and automation.

- As the glass etching process is very complicated and it is hazardous to the worker, and also many child labours are involved in etching process and it takes more time. Alternative glass-machining methods are available but they all have certain disadvantages.
- This project is a solution over the limitations of such conventional etching process. The aim to make an automated glass frosting machine at low cost. Because of the powder particles (contamination) and the large minimum feature sizes, the process is carried out with greater flexibility and accurately.

6. CONCEPT DEVELOPMENT

6.1 Action Plan

The whole work of development is divided into two stages

1. Design and fabrication of Glass frosting machine.
2. Developing a user friendly interface on computer.

6.1.1 Design and Fabrication Of Glass Frosting Machine

Before starting the actual fabrication, the study of various types of glasses is done. The material and specification of all components is decided according to size of glass. The assembly modeling and its simulation carried out through Solid works software and fabrication is done. The methodology is represented in pyramid form as shown below in fig 3.1.

6.1.2 Developing A User Friendly Interface On Computer

In the second step of development, a user interface is designed with the help of KIEL software. The event programming (using C programming language) is done for frosting on glass.

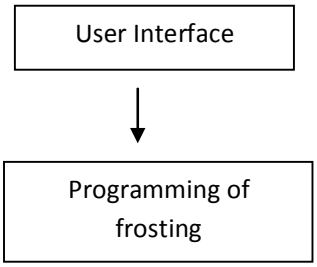

Figure. 1 Developing a User Friendly Interface on Computer

The present invention relates to machine and to certain components, Therefore design for chemically frosting articles made of glass. In spite of increasing demand for such articles, they are still produced on handicraft scale essentially involving manual labor and low productivity. The objective of the proposed project is to make an automated glass frosting machine at low cost. Because of the powder particles (contamination) and the large minimum feature sizes, the process is carried out with greater flexibility and accurately. The aim of the project is to develop a computer assisted glass

frosting machine with two axes X & Y will be controlled by computer.

Glass frosting involves creating a design on a glass surface by applying an acidic or abrasive substance. Usually found in the form of a cream, etching substances contain caustic chemicals such as ammonium and fluoride as the active ingredients. These are to be handled by adults or completed under adult supervision, as misuse or close contact with etching chemicals may require immediate medical attention.

6.2 Proposed Concept:

The box type configuration will be providing the required rigidity and robustness. This type will be beneficial for glass, as the structure have minimum basic configuration, easy for fabrication point of view. It is simplest structures with fewer complications. The working area of glass will be A4 size. Within this area the glass engraving will be done

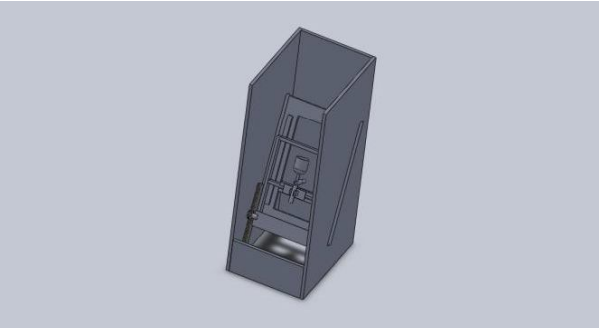

Figure 2. Proposed Concept

Components:

- Glass
- Sandblasting gun
- Glass mounting frame
- Channels
- Rack and Pinion
- DC. Motor
- Nozzle mounting frame
- Microcontroller
- LCD
- Compressor (6-9 bar)

7. INTERFACING

7.1 The complete interface process is done in following sequence.

1. Construction of Hardware by using suitable electronic component according to requirement.
2. Programming for the software interface by using C language.
3. Integration of above three to get a complete assembly.

7.2 steps of Programming in C

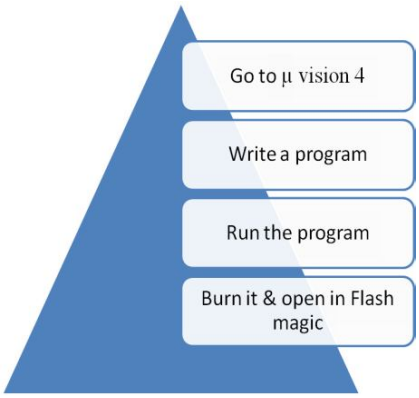

Figure 3. Steps of Programming

8. RESULTS AND DISCUSSION

1. It is safer than machine than conventional one because the whole sandblasting is controlled by computer system.

2. 2. As the construction is of box type and door is provided so the operation is performed in cabin so dust will be inside the cabin, it will not affect the worker. As in conventional one the worker needs hand gloves, goggles' etc. for protection.

3. 3. It provides greater accuracy for repetitive work which is quite difficult in conventional one. Conventional requires more attention for getting profiles on various glasses.

4. 4. The most important it increases more productivity and reduced the skilled operator, while in conventional one the skilled worker are involved.

5. The experiment is conducted Successfully with the help of Compressor; also the material removal rate is calculated by using Formula

$$Q = XZd^3v^{3/2}\left\{\frac{P}{12Hw}\right\}^{3/4}$$

Table No.1 MRR at various Pressures

S.No	Pressure (Kgf/cm2)	(MRR) (mg/min)
1.	5	18
2.	6	21
3.	7	23
4.	8	26

9. FUTURE SCOPE

The development of Glass frosting leads to follow

1. In addition to the knowledge, It requires expertise of other areas like electronics and Computer science.
2. The Proposed model can reduce the labor & increase productivity. It uses a closed loop system for feedback; hence precise movement can be obtained.
3. In CAD/CAM based method, the various types of frosting profiles is drawn by using tools of CAD software's like PRO-E, CATIA etc. This coding is done by using CAM software's and finally passed to machine. On the basis of this concept, in future machine can be desig

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International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

Parametric Investigation and Optimization of Co_2 Laser Cutting process used for Cutting Hardox-400 materials

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Abstract: A laser uses amplified & stimulated radiation of light. Laser machine is a device which is used to generate & amplifies light. Laser stands for Light Amplification by Stimulated Emission of Radiation. Laser machine is an electrical-optical device that produces coherent radiation. Simply put, a laser is a device that creates and amplifies a narrow, intense beam of coherent light. This paper reviews some of the experimental investigates different process parameter like cutting speed, laser power, gas pressure, pulse frequency on hardox 400 material. Then the CO2 laser cutting experiment was made by using 8 mm thickness hardox 400 material. In this experiment work it is focused to establish relation of different process parameter on cut quality, which is decided by the surface roughness, kerf width, and perpendicularity.

Keywords: Hardox-400, CO2 laser cutting, cutting quality,

1. INTRODUCTION

Laser, which stands for Light Amplification by Stimulated Emission of Radiation, is an electrical-optical device that produces coherent radiation. Simply put, a laser is a device that creates and amplifies a narrow, intense beam of coherent light. Now days, laser is widely applied in today's industry. A laser comprises three principal components, namely, the lasing medium, means of exciting the lasing medium into its amplifying state (lasing energy source), and optical delivery/feedback system. Additional provisions of cooling the mirrors, guiding the beam and manipulating the target are also important. Lasers are widely used in industry for cutting and boring metals and other materials, in medicine for surgery, and in communications, scientific research, and holography. They are an integral part of such familiar devices as bar code scanners used in supermarkets, scanners, laser printers, and compact disk players [6].

Laser cutting is a process in which the material is heated to its melting or vaporization temperature. Heating is achieved by concentrating the energy in a very small spot. This allows the cutting of almost all types of materials with thickness of up to 20 mm in the case of steel sheets without the need for very high levels of energy . There are different laser generators depending on the type of the laser-active material they use. Each type of laser creates a laser beam at a given wavelength. The CO2 generators are the most used for steel cutting with a wavelength 10.6 mm, whilst the Nd: YAG lasers generate a beam with a wavelength of 1.06 mm. In general, the Nd: YAG lasers wavelength is better absorbed by most of materials (copper, aluminum, precious metals,). Steel, however, has acceptable absorption levels for the beam generated by CO2. This, added to the fact that these CO2 generators are more powerful and cheaper, explains why their use in industry is much more widespread. Once the beam has been generated, a lens system focuses the beam on a point with diameters of around 0.2 mm. The focusing of the beam allows for high energy densities to be reached, a typical value is about 1.4 _ 1010 W/m2. The high power density concentrated on the spot vaporizes almost all types of material (as long as there is a certain amount of beam absorption) [3].

2. EXPERIMENTAL PROCEDURE AND OPERATION PARAMETER

2.1 Material:

The base material used in this study was hardox-400 sheet 6 mm thick, whose chemical composition and mechanical properties are listed in Table 1. This hardox-400.

Table 1. Chemical composition of hardox-500 Material

2.2 Taguchi methodology based experiments:

These experiments were performed with a 3.5 kW CO2

C	Si	Mn	P	Cr	Mo	B
0.13	0.53	1.24	0.002	0.65	0.019	0.002

(omada),To prevent the instability and damage caused by back reflections, the cavity is isolated by using a beam bender mirror with a multilayer coating that absorbs the back reflected laser beam. The laser beam was focused using a 127mm focal length lens except for the tests conducted to detect the influence of this parameter. For this purpose, lenses with 127 and 190.5mm were used. Tests were conducted in continuous wave (CW) and in pulsed mode. In CW mode, when the laser source delivers a constant power, the experiments were performed varying one factor at a time. The ranges of cutting parameter are summarized in Table 2.

A commercial cutting head incorporating a conical converging coaxial nozzle with a 1.5 mm exit diameter was employed to supply the assist gas in a coaxial manner with the laser beam. In the tests conducted to reveal the influence of the nozzle exit on the quality of the cuts, nozzles with an exit diameter of 0 1.5 mm were also used. The distance from the lower part of the nozzle to the plate (also known as stand-off distance) was fixed at 1.5mm except for the tests conducted to

reveal the influence of this parameter. Compressed air, nitrogen and oxygen at various pressures were used as assist gases.

Table 2. Control factors and theirs level use in experiment

Symbol	Factor	Unit	Level-1	Level-2	Level-3
A	Power	watt	1300	1500	1700
B	Gas pressure	Bar	0.5	0.6	0.7
C	Cutting speed	Mm/ min	300	500	700
D	Pulse frequency	Hz	20	25	30

An experimental performance is carried out which analysis of co2 laser cutting process for hardox – 400 Sheet. It shows that by proper control of the cutting parameter, good quality cuts are possible at high cutting rates. Some characteristics such as the surface roughness, kerf width, and perpendicularity as output parameters also discussed.

2.2.1 Surface Roughness Measurement

The surface roughness for all trial runs is measured with profilometer named as sj-201. After the measuring number of samples through surface roughness tester (SJ -201) In which we have measured L1, L2, L3 sample lengths and considered their average value in terms of length in mm. in figure we have described measuring surface roughness of the sample and in table shown results of surface roughness test according to experiment.

Figure 2 Measuring surface roughness of the sample

Table 3. Plan of experiments

Trial no.	A Power (W)	B Gas Press (Bar)	C Cutting Speed (mm)	D Pulse Freq. (H_Z)	Surface roughens (µm)
1	1300	0.5	300	20	6.5
2		0.5	500	25	7.43
3		0.5	700	30	7.04
4		0.6	300	25	9.0
5		0.6	500	30	8.06
6		0.6	700	20	8.91
7		0.7	300	30	12.32
8		0.7	500	20	6.75
9		0.7	700	25	7.13
10	1500	0.5	300	25	11.4
11		0.5	500	30	9.59
12		0.5	700	20	6.83
13		0.6	300	30	12.20
14		0.6	500	20	14.86
15		0.6	700	25	9.5
16		0.7	300	20	16.59
17		0.7	500	25	12.78
18		0.7	700	30	7.97
19	1700	0.5	300	30	13.56
20		0.5	500	20	16.27
21		0.5	700	25	14.86
22		0.6	300	20	18.19
23		0.6	500	25	16.41
24		0.6	700	30	13.44
25		0.7	300	25	11.24
26		0.7	500	30	17.23
27		0.7	700	20	15.88

Table 4. Layout Using L_{27}

Trial no	A	B	C	D
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	2	1	2
5	1	2	2	3
6	1	2	3	1
7	1	3	1	3
8	1	3	2	1
9	1	3	3	2
10	2	1	1	2
11	2	1	2	3
12	2	1	3	1
13	2	2	1	3
14	2	2	2	1
15	2	2	3	2
16	2	3	1	1
17	2	3	2	2
18	2	3	3	3
19	3	1	1	3
20	3	1	2	1
21	3	1	3	2
22	3	2	1	1
23	3	2	2	2
24	3	2	3	3
25	3	3	1	2
26	3	3	2	3
27	3	3	3	1

2.2.2 Kerf width Measurement

The kerf width measurement was done by equipment using by digital camera and image tool programs. In which first digital camera was used to take the photographs of top bottom cut kerf of test piece, after that the photographs were transmitted in computer then after uploaded in image tool software for used to measure length along kerf gap.

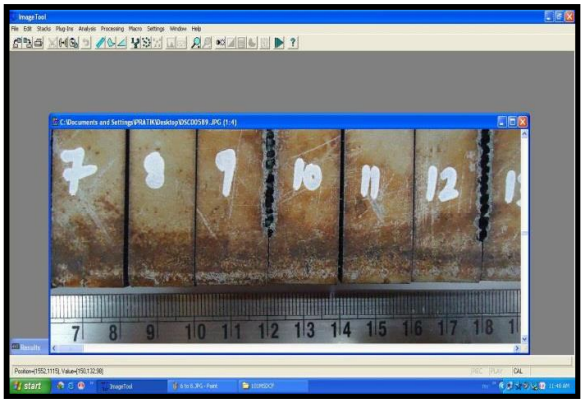

Figure 3 Print screen of image tool software

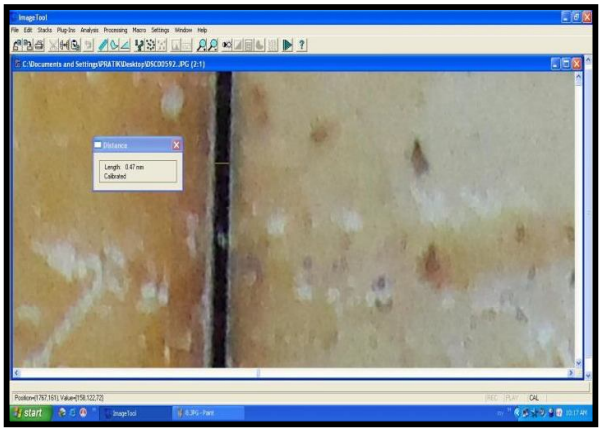

Figure 4 Print screen of image tool software measuring kerf width

We have performed experiments then after measured kerf width via image tool software according to above figure one by one take print screen shots and measuring kerf width values and displayed in results table below.

Table 5.3. Results of kerf width obtained from experimental work

Trial no.	A Power (W)	B Gas Press (Bar)	C Cutting Speed (mm)	D Pulse Freq. (H_Z)	Kerf Width (mm)
1		0.5	300	20	0.36
2		0.5	500	25	0.23
3		0.5	700	30	0.25
4		0.6	300	25	0.19
5	1300	0.6	500	30	0.64
6		0.6	700	20	0.30
7		0.7	300	30	0.18
8		0.7	500	20	0.98
9		0.7	700	25	0.32
10		0.5	300	25	0.85
11		0.5	500	30	0.96
12		0.5	700	20	0.24
13		0.6	300	30	0.85
14	1500	0.6	500	20	0.88
15		0.6	700	25	0.48
16		0.7	300	20	0.97
17		0.7	500	25	1.0
18		0.7	700	30	0.36
19		0.5	300	30	0.93
20		0.5	500	20	0.67
21		0.5	700	25	1.78
22		0.6	300	20	1.36
23	1700	0.6	500	25	0.79
24		0.6	700	30	2.30
25		0.7	300	25	1.35
26		0.7	500	30	1.26
27		0.7	700	20	2.40

2.2.3 Perpendicularity Measurement

The perpendicularity measurement was done with the work piece cut through to reveal the cut surface variation in which same procedure as kerf width measurement using by digital camera and image tool programs. In which first digital camera was used to take the photographs of cut surface profile of test piece, after that the photographs were transmitted in computer then after uploaded in image tool software for used to measure length along cut profile in figure described sample of print screen of perpendicularity measurement.

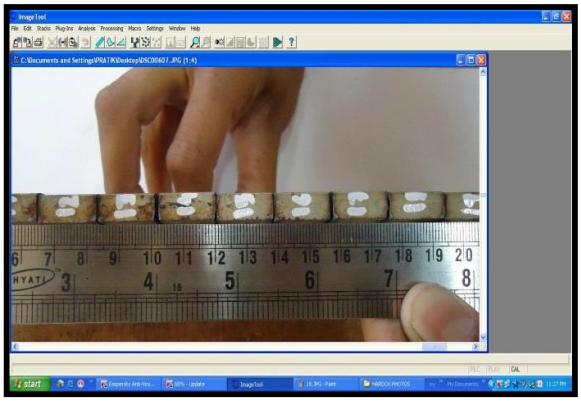

Figure 5 Print screen of perpendicularity sample of image tool software

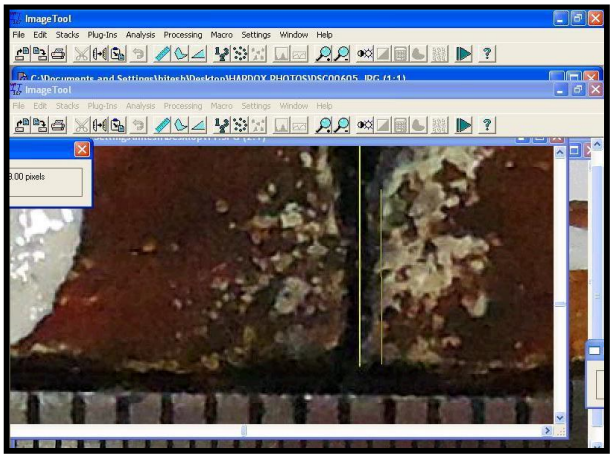

Figure 6 Print screen of measuring perpendicularity on image tool software

We have performed experiments then after measured perpendicularity measurement via image tool software according to above figure one by one take print screen shots and measuring perpendicularity measurement values and displayed in results table below.

Trial no.	A Power (W)	B Gas Press (Bar)	C Cutting Speed (mm)	D Pulse Freq. (H_Z)	Perpendicularity (radian)
1		0.5	300	20	0.018
2		0.5	500	25	0.015
3		0.5	700	30	0.014
4		0.6	300	25	0.013
5	1300	0.6	500	30	0.018
6		0.6	700	20	0.017
7		0.7	300	30	0.015
8		0.7	500	20	0.016
9		0.7	700	25	0.013
10		0.5	300	25	0.020
11		0.5	500	30	0.014
12		0.5	700	20	0.013
13		0.6	300	30	0.014
14	1500	0.6	500	20	0.018
15		0.6	700	25	0.015
16		0.7	300	20	0.021
17		0.7	500	25	0.015
18		0.7	700	30	0.012
19		0.5	300	30	0.023
20		0.5	500	20	0.021
21		0.5	700	25	0.022
22		0.6	300	20	0.020
23	1700	0.6	500	25	0.017
24		0.6	700	30	0.026
25		0.7	300	25	0.018
26		0.7	500	30	0.017
27		0.7	700	20	0.024

Table 5.4 Results of Perpendicularity obtained from Experimental work

3. RESULT AND DISCUSSION

Kerf width measurements at the top and bottom surfaces of the sample indicated that the top kerf width was slightly larger than that at the bottom for most of the cutting conditions, which is indicative of the tapered nature of the laser cut as caused by loss of beam intensity, defocusing, or loss of gas pressure across the thickness of the cut. It was also observed that the kerf width slightly increased with an increase in cutting distance along the cut [7, 8].

Cutting speed and laser power has important role in achieving desire kerf width in cutting of hardox-400.here I have got results on different laser power 1300, 1500 and 1700.

3.1 Effect of laser power at 1300w

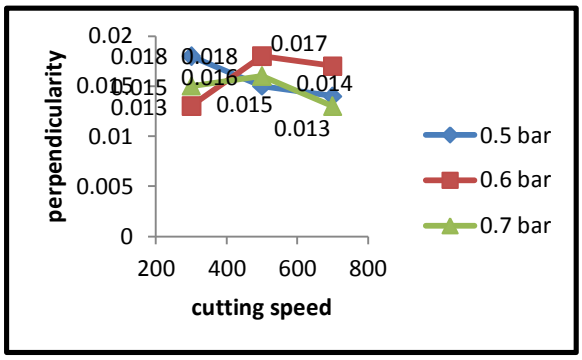

Figure.7 graph of cutting speed Vs. Perpendicularity with laser power 1300 watt

In above figure in which cutting speed Vs. perpendicularity at three different gas pressure with constant laser power 1300 watt indicated. when gas pressure 0.5 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity is decrease from 0.018 radian to 0.015 radian similarly cutting speed 500 to 700 mm/min then after increases form 0.015 radian to 0.014 radian. In gas pressure 0.6 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity increase from 0.013 radian to 0.018 radian is similarly cutting speed 500 to 700 mm/min then after perpendicularity decrease from 0.018 radian to 0.017 radian. . in gas pressure 0.7 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity is increase from 0.015 radian to 0.016 radian similarly cutting speed 500 to 700 mm/min then after perpendicularity decrease from 0.016 radian to 0.013 radian.

3.2 Effect of laser power at 1500w

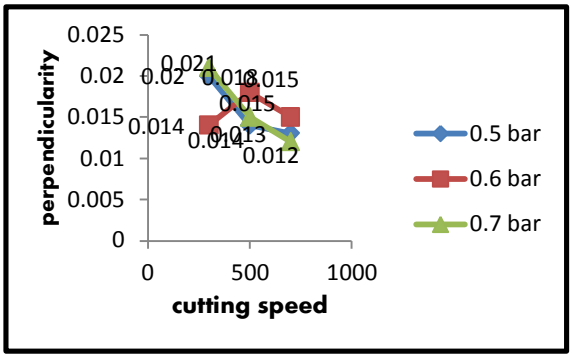

Figure 8 Graph of cutting speed Vs. Perpendicularity with laser power 1500 watt

In above figure in which cutting speed vs. perpendicularity at three different gas pressure with constant laser power 1500 watt indicated. When gas pressure 0.5 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity is decrease from 0.020 radian to 0.014 radian similarly cutting speed 500 to 700 mm/min then after decreases form 0.014 radian to 0.013 radian. In gas pressure 0.6 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity increase from 0.014 radian to 0.018 radian is similarly cutting speed 500 to 700 mm/min then after perpendicularity decrease from 0.018 radian to 0.015 radian. In gas pressure 0.7 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity decrease from 0.021 radian to 0.015 radian is similarly cutting speed 500 to 700 mm/min then after perpendicularity decrease from 0.015 radian to 0.012 radian.

3.3 Effect of laser power at 1700w

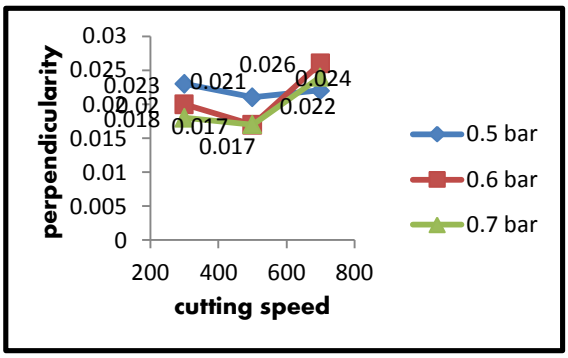

Figure 9 graph of cutting speed Vs. Perpendicularity laser power 1700 watt

In above figure in which cutting speed vs. perpendicularity at three different gas pressure with constant laser power 1700 watt indicated. when gas pressure 0.5 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity is decrease from 0.023 radian to 0.021 radian similarly cutting speed 500 to 700 mm/min then after increases form 0.021 radian to 0.022radian. In gas pressure 0.6 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity decrease from 0.020 radian to 0.017 radian is similarly cutting speed 500 to 700 mm/min then after perpendicularity increase from 0.017 radian to 0.026 radian. In gas pressure 0.7 bar in which cutting speed increase 300 to 500 mm/min then perpendicularity decrease from 0.018 radian to 0.017 radian is similarly cutting speed 500 to 700 mm/min then after perpendicularity increase from 0.017 radian to 0.024 radian.

4. CONCLUSION

After studied the performance the of CO_2 laser cutting of hardox- 400 for 8 m thickness with oxygen assistant gas cut by CO_2 laser cutting machine made by omada laser Technology. After the experiment the cut quality was defined by focusing on surface roughness, kerf width and perpendicularity.

After studied experiment work the reason can be clear that when laser power increase 1700 watt with medium gas pressure up to 0.6 bar ,low cutting speed ,low pulse frequency caused roughly cut result .if we if decrease laser power up to 1300 watts and also with low gas pressure 0.5 bar or low cutting speed with low pulse frequency than we got minimum surface roughness. So here gas pressure has important role played for achieving desire surface roughness in co2 laser cutting of hardox -400 materials of 8 mm thickness and optimum results for surface roughness displayed below in result table.

Sr no.	Power (Watt)	Gas Pressure (bar)	Cutting Speed (mm/min)	Pulse freq. (H_Z)	Surface Roughness (µm)
1	1300	0.5	300	20	5.46
2	1700	0.6	300	20	18.19

After the experiment performed that it can be noticeable that at lower laser power 1300 watts ,medium gas pressure 0.6 bar and cutting speed decreasing up to 300 mm/min pulse frequency 25 (Hz) then got minimum kerf width. At higher laser power 1700 watts , high gas pressure up to 0.7 bar ,higher cutting speed 700 mm/min and pulse frequency 20 (Hz) in order to get maximum kerf width so optimum results for kerf width was indicate in result table below.

Sr no.	Power (Watt)	Gas Pressure (bar)	Cutting Speed (mm/min)	Pulse freq. (H_Z)	Kerf Width (mm)
1	1300	0.6	300	25	0.19
2	1700	0.7	700	20	2.40

In our experiment work it can be clear that perpendicularity increased at higher power (1700 watt) , higher cutting speed 700 mm/min. and pulse frequency (25 hz) when laser power is lower (1300 watt) and lower cutting speed (300 mm/min) and pulse frequency (30 Hz) then got minimum perpendicularity so here cutting speed and pulse frequency has important role played for achieving desire perpendicularity in co2 laser cutting of hardox -400 material of 8 mm thickness and optimum results for perpendicularity displayed below in result table.

Sr no.	Power (Watt)	Gas Pressure (bar)	Cutting Speed (mm/min)	Pulse freq. (H_Z)	Perpendicularity (mm)
1	1300	0.6	300	25	0.013
2	1700	0.6	700	30	0.026

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International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

Solving Multi-level, Multi-product and Multi-period Lot Sizing and Scheduling Problem in Permutation Flow Shop

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Abstract: In this paper, a new model of capacitated lot sizing and scheduling in a permutation flow shop is developed. In this model demand can be totally backlogged. Setups can be carryover and are sequence-dependent. It is well-known from literatures that capacitated lot sizing problem in permutation flow shop systems are NP-hard. This means the model is solved in polynomial time and metaheuristics algorithms are capable of solving these problems within reasonable computing load. Metaheuristic algorithms find more applications in recent researches. On this concern this paper proposes two evolutionary algorithms, one of the most popular namely, Genetic Algorithm (GA) and one of the most powerful population base algorithms namely, Imperialist Competitive Algorithm (ICA). The proposed algorithms are calibrate by Taguchi method and be compared against a presented lower bound. Some numerical examples are solved by both the algorithms and the lower bound. The quality of solution obtained by the proposed algorithm showed superiority of ICA to GA.

Keywords: permutation flow shop; evolutionary algorithms; lot sizing and scheduling

1. INTRODUCTION

The multilevel lot sizing problem concerns how to determine the lot size for producing or procuring an item at each and sequencing is to determine job ordering on each level. The objective of lot sizing and sequencing generally is to minimize the sum of the total setup cost and inventory holding cost. Lot sizing and sequencing problem plays an important role in the efficient operation of modern manufacturing and assembly processes.

The flow shoplot sizing has been a very extensively researched area since the seminal paper of Johnson [1]. In the flowshop problem (FSP) a set ofunrelated jobs are to be processed on a set of machines. These machines are disposed in series and each job has to visit all of them in the same order. A special case of flow shop that assumes the same order of products in all machines is called permutation flow shop. In this paper we consider a permutation flow shop problem with setup carryover, setup sequence-dependent and backlogging.

In highly capacitated environments as well as in many real-life situations, the inclusion of back orders is crucial because otherwise, no feasible plan would exist and the respective result that no feasible solution can be found is of minor importance in practical settings. On the other hand, in many real-life manufacturing environment the capacity of the machines are limited, or for cost saving reasons, it might be useful to produce a product volume in a period other than its demand period to save setup time and costs. In traditional lot sizing models producing of a product in a period before its delivery to the customer is permitted. In this case, inventory cost occurs. In our case, it is also possible that the product cannot be delivered on time. It is then backlogging occurs and backlogging costs are incurred for every unit at period of the delay. While only few lot sizing approaches consider the possibility of back ordering, it is of great importance in practical settings: If capacity is limited, some productsmay have to be backlogged [2].

Quadt and Kuhn [3] investigated a capacitated lot sizing and scheduling problem with setup times, setup carryover, backorders, and parallel machines. They formulated a mixed integer formulation of the problem and a new solution procedure. The solution procedure was based on a novel "aggregate model" which uses integer instead of binary variables. Song and Chan [4] considered a single item lot sizing problem with backlogging on a single machine at a finite production rate. The objective function was to minimize the total cost of setup, stockholding and backlogging to satisfy a sequence of discrete demands.Other researchers have considered backlogging including Wolsey and Pochet [5], Cheng et al. [6]and Karimi et al.[7].

Graham et al. [8] showed that the permutation flow shop scheduling problem is strongly *NP*-complete. Since then many researches have been attracted to develop heuristic and metaheuristic algorithms for these problems. Among researchers that employed metaheuristic we can cite to Mohammadi et al. [9]. They employed a GA as a solution approach. Their proposed algorithm was used for a simultaneous lot sizing and sequencing problem in permutation flow shops involving sequence-dependent setups and capacity constraints. Ruiz et al. [10]proposed new genetic algorithms for solving the permutation flow shop scheduling. The minimization of the total completion time or makespanwas considered as theoptimization criterion. They used new genetic operators, advanced techniques like hybridization with local search and an efficient population initialization as well as a new generational scheme. The

following is brief review of studies that have considered GA as a solution approach for a permutation flow shop problem. The authors employed their proposed GA for different optimization criteria. A GA was used inAllada and Ruiz [11]study with total tardiness minimization criterion. Tseng and Lin [12]have minimized makespan in a permutation flow shop problem.TavakkoliMoghaddam et al. [13]employed a GA to minimize the makespan. Goren [14]provided an overview of recent advances in the field in order to highlight the many ways GAs can be applied to various lot sizing models.

Despite the fact that GA is one of the most popular algorithm,other metaheuristic algorithms have been used broadly by authors. Among metaheuristics, ICA is a novel population-based evolutionary algorithm proposed by Atashpaz-Gargari and Lucas [15].ICA is a novel socio-politically motivated metaheuristic algorithm inspired by imperialist competition. The results show that the algorithm performs significantly better than existing algorithms like genetic algorithm (GA), simulated annealing (SA), tabu search (TS), and particle swarm optimization (PSO) [16].So we propose a novel imperialist algorithm (ICA) that employed some genetic operators during local search.Many researchers have employed ICA as a solution approach for flow shops. As instances, Attar et al. [17]proposed a novel imperialist competitive algorithm to solve flexible flow shop scheduling problem the optimization criterion was minimization maximum completion time.Shokrollahpour et al. [18] used ICA for a two-stage assembly flow shop scheduling problem with minimization of weighted sum of makespan and mean completion time as the objective function. Rajabioun et al. [19],Khabbazi et al. [20],Kaveh and Talatahari [21] Lucaset al. [22],Nazari-Shirkouhi et al. [23] andSarayloo and Tavakkoli-Moghaddam[24] are other related study that employed ICA.

In literature, other metaheuristics have been employed by researchers. The following shows recent studies about using different kind of metaheuristics in permutation flow shop. Quan et al. [25]used PSO in permutation flow shop with makespan criterion. Ant Colony Optimization is employed byUdomsakdigool and Khachitvichyanukul [26].

As mentioned above, despite backlogging importance in practical settings, only few researchers have addressed capacitated lot sizing problems with back ordering especially in case of permutation flow shop. To the best of our knowledge, this is the first paper that deals with setup sequence-dependent, setup carryover and backlogging in a multi-level, multi-machine and multi-period permutation flow shop environment and proposes two metaheuristics to solve the model and develops a lower bound to compare algorithms.

This paper is organized as follows:in next section, notations used in the formulation are described and a lower bound is presented. In section 3 the genetic algorithm and in section 4 imperialist algorithm are proposed. In subsequence section, the algorithms are calibrated by Taguchi method and theperformance of proposed algorithms is evaluated. Finally, Section 6 is devoted to conclusions and recommendation for future studies.

2. PROBLEM FORMULATION

The following notations are used in the model:

2.1. Notations and assumptions

2.1.1 Indices

i, j, k	Index of production type
n	Index of product type
n'	Designation for a specific setup number
m	Index of level of production
t	Index of period

2.1.2 Parameters

T	Planning horizon
N	Number of different products
M	Number of production levels/number of machines
$bigM$	A large real number
$C_{m,t}$	Available capacity of machine *m*in period *t* (in time units)
$d_{j,t}$	External demand for product *j* at the end of period *t* (in units of quantity)
$h^{+}_{j,m}$	Storage costs unit rate for product *j* in level *m*.
$h^{-}_{j,t}$	Shortage costs unit rate for product *j* at the end of period *t*.
$b_{j,m}$	Capacity of machine *m* required to produce a unit of product (or shadow product) *j* (in time units per quantity units).
$P_{j,m,t}$	Production costs to produce one unit of product *j* on machine *m* at period *t* (in money unit per quantity unit).
$S_{i,j,m}$	Sequence-dependent setup time for the setup of the machine *m* from production of product *i* to production of product *j* (in time units); for $i \neq j, S_{i,j,m} \geq 0$ and $i = j, S_{i.j.m} = 0$.
$W_{i,j,m}$	Sequence-dependent setup cost for the setup of the machine *m* from production of product *i* to production of product *j* (in money units); for $i \neq j, W_{i,j,m} \geq 0$ and $i = j, W_{i.j.m} = 0$.
j_{0m}	The starting setup configuration on machine *m*.

2.1.3 Decision variables

$I^{+}_{j,m,t}$	Stock of product *j* at level *m* at the end of period *t*.
$I^{-}_{j,t}$	Shortage of product *j* at the end of period *t*.
$y^{n}_{i,j,t}$	Binary variable, which indicates whether the *n*th setup on machines at period *t* isfrom product *i* to product *j* ($y^{n}_{i,j,t} = 1$) or not ($y^{n}_{i,j,t} = 0$).
$x^{n}_{i,j,m}$	Quantity of product *j* produced after *n*th setup on machine *m* at period *t*.

$q^n_{i,j,m}$ Shadow product: the gap (in quantity units) between *n*th setup (to product *j*) on machine *m* at period *t* and its related production in order to ensure that direct predecessor of this product (production of product *j* on machine *m* at period *t*) has been completed.

To formulate this model the following assumptions are considered:

- Several products are produced in a flow shop environment and each product can be produced only on one machine at the same time,
- Inventory cost incurred when a product unit is hold between a particular period,
- If the product cannot be delivered on time shortage cost is incurred,
- Setup times reducing machine capacity and each machine is constrained in capacity
- Setups are sequence-dependent and must be complete in a period.
- There must be precisely N (number of products) setups in each period on each machine, even if a setup is just from a product to itself, with respect to this issue that setup time (and cost) from a product to itself is zero

The mathematical model in this paper is described on the basis of the above assumptions and notations

2.1. Mathematical formulation

Capacitated lot sizing focuses on how to make lot sizing planning and sequencing focuses on the order of each product should be produced to minimize total cost. The objective function is to find an optimal lot sizing and sequencing that minimize setup, inventory, production and backlogging costs.

$$min \sum_{n=1}^{N}\sum_{j=1}^{N}\sum_{i=1}^{N}\sum_{m=1}^{M}\sum_{t=1}^{T} W_{i,j,m}.y^n_{i,j,t} + \sum_{n=1}^{N}\sum_{j=1}^{N}\sum_{m=1}^{M}\sum_{t=1}^{T} P_{j,m,t}.x^n_{j,m,t} + \sum_{j=1}^{N}\sum_{m=1}^{M}\sum_{t=1}^{T} h^+_{j,m}.I^+_{j,m,t} + \sum_{j=1}^{M}\sum_{t=1}^{T} h^-_{j,t}.I^-_{j,t} \quad (1)$$

Subject to

$$d_{j,t} = I^+_{j,M,t-1} + \sum_{n=1}^{N} x^n_{j,M,t} - I^+_{j,M,t} - I^-_{j,t-1} + I^-_{j,t};\quad j = 1,\dots,N,\quad t = 1,\dots,T \quad (2)$$

$$I^+_{j,m,t-1} + \sum_{n=1}^{N} x^n_{j,m,t} = I^+_{j,m,t} + \sum_{n=1}^{N} x^n_{j,m+1,t};\quad j = 1,\dots,N,\ m = 1,\dots,M-1,\quad t = 1,\dots,T \quad (3)$$

$$\sum_{n=1}^{n'}\sum_{i=j0}^{N}\sum_{j=1}^{N} y^n_{i,j,t}.S_{i,j,m} + \sum_{n=1}^{n'}\sum_{j=1}^{N} b_{j,m}.q^n_{j,m,t} + \sum_{n=1}^{n'}\sum_{j=1}^{N} b_{j,m}.x^n_{j,m,t} \le \sum_{n=1}^{n'}\sum_{i=j0}^{N}\sum_{j=1}^{N} y^n_{i,j,t}.S_{i,j,m+1} + \sum_{n=1}^{n'}\sum_{j=1}^{N} b_{j,m+1}.q^n_{j,m+1,t} + \sum_{n=1}^{n'-1}\sum_{j=1}^{N} b_{j,m+1}.x^n_{j,m+1,t};\quad n' = 1,\dots,N,\ m = 1,\dots,M-1,\ t = 1,\dots,T \quad (4)$$

$$\sum_{n=1}^{N}\sum_{i=j0}^{N}\sum_{j=1}^{N} y^n_{i,j,t}.S_{i,j,m} + \sum_{n=1}^{N}\sum_{j=1}^{N} b_{j,m}.x^n_{j,m,t} + \sum_{n=1}^{N}\sum_{j=1}^{N} b_{j,m}.q^n_{j,m,t} \le C_{m,t};\quad m = 1,\dots,M, t = 1,\dots,T \quad (5)$$

$$x^n_{j,m,t} \le \left(\frac{C_{m,t}}{b_{j,m}}\right).\sum_{i=j0,i\neq j(for(n>1))}^{N} y^n_{i,j,t},\quad n = 1,\dots,N,\ j = 1,\dots,N, m = 1,\dots,M,\ t = 1,\dots,T \quad (6)$$

$$q^n_{j,m,t} \le \left(\frac{C_{m,t}}{b_{j,m}}\right).\sum_{i=j0}^{N} y^n_{i,j,t},\ n = 1,\dots,N,\ j = 1,\dots,N,\ m = 1,\dots,M,\quad t = 1,\dots,T \quad (7)$$

$$y^1_{j,i,1} = 0\ j \neq j_{0m},\quad i = 1,\dots,N \quad (8)$$

$$\sum_{i=1}^{N} y^1_{j_{0m},i,1} = 1, \quad (9)$$

$$\sum_{j=j0}^{N} y^n_{j,i,t} = \sum_{k=1}^{N} y^{n+1}_{i,k,t}\quad i = 1,\dots,N,\ n = 1,\dots,N-1,\ m = 1,\dots,M,\quad t = 1,\dots,T \quad (10)$$

$$y^n_{i,j,t} = 0\ or\ 1 \quad (11)$$

$$I^{+}_{j,m,t}, I^{-}_{j,t}, x^{n}_{j,m,t}, q^{n}_{j,m,t} \geq 0 \quad (12)$$

$$I^{+}_{j,m,0} = 0, \quad j = 1,\ldots,N, \quad m = 1,\ldots,M \quad (13)$$

In this model, the objective function is Equation (1). The backlogging or storage at the end of each period is considered by Equation (2). Constrain (3) ensures total of in-flows to each node is equal to of out-flows from that node. Equation (4) ensures within one period each typical product j one machine m is produced before its direct successor. The capacity constraints of machines are considered by Equation (5). Equation (6) respects setups in production process. Equation (7) indicates the relationship between shadow products and setups. Constraints (8) and (9) ensure that for each machine, the first setup at the beginning of the planning horizon is from a defined product. Equation (10) represents the relationship between successive setups. The type of variables is defined by Equations (11) and (12) and finally Equation (13) indicates that at the end of planning horizon there is no on-hand inventory.

2.3. Lower bound

In this section we present a lower bound that developed by Mohammadi et al. [27]. We first relax binary variables to continuous variables that fall in [0, 1].

Then we add following equation to relaxed model:

$$\sum_{i=j0}^{N} y^{1}_{i,j,t} + \sum_{i=1,i\neq j}^{N} \sum_{n=2}^{N} y^{n}_{i,j,t} = a_{j,t} \quad (14)$$

In this equation $a_{j,t}$ is binary variable.

Equation (14) was proved that is valid to model. We refer the proof of this equation to Mohammadi et al [27].

3. GENETIC ALGORITHM

GAs are probabilistic search optimization algorithms that were inspired by the process of natural evolution and the principles of survival of the fittest [28].Genetic Algorithms (GAs) can be employed to find a near-optimal solution for *NP*-hard problems. GAs evolves a population of individuals according to the progress of algorithm to reach a good solution. Genetic operators (such as natural selection, mutation, and cross over) manipulate individuals in a population of solution over several iterations to improve their fitness.The algorithm generates a new candidate pool of solutions iteratively from the presently available solutions and replaces some or all of the existing members of the current solution tool with the newly created feasible solutions.

We first present a simple and effective heuristic to generate initial solution and then discuss the issue of encoding in our case aninteger array representation. We then turn to the evolutionary stages of the algorithm and the specific genetic operators that have been designed to increase search efficiency.

Initial Population

A genetic algorithm starts with popularly an initial population of feasible solutions. Initial population can affectsthe performance of GAs. So that a simple and effect heuristic is used for $t = 1$to $T$and is described as follows:

(1) The products are sorted in the decreasing order of $W_{j,m} = \sum_{i=1}^{N} W_{i,j,m}; j = 1,\ldots,N.$

(2) Let $[i]$ indicate the ith product in an ordered sequence in this heuristic.

For $[i] = 1$ to N:

(a) Consider inserting product $[i]$ into every position.

(b) Calculate the sum of setup costs for all products scheduled so far using the actual setup costs.

(c) Place product i in the position with the lowest resultant sum of setup costs.

With using this method, M different initial populations is produced (for $m = 1,\ldots,M$), the remaining initial populations have been generated randomly.In this way, binary variables are coded in the form of matrices with $N \times T$ dimensions.

In Figure1 a sample chromosome with T =3, N =3 is depicted.

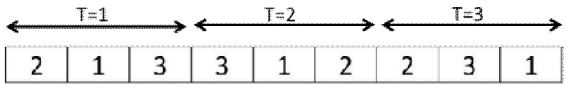

Figure 1. A chromosome representation

In Figure 1 an encoded binary variables have been shown. The corresponding decoded binary variablesin this chromosomeduring period T=1 are, $y^{1}_{0,2,1} = y^{2}_{2,1,1} = y^{3}_{2,3,1} = 1$ and the corresponding decoded binary variables to this chromosome during period T=2 are, $y^{1}_{0,3,2} = y^{2}_{3,1,2} = y^{3}_{1,2,2} = 1$and finally for period T=3, $y^{1}_{0,2,3} = y^{2}_{2,3,3} = y^{3}_{3,1,3} = 1$and other binary variables would get value 0.With encoding of the binary variables, we are able to employ crossover and mutation operators more efficientlyand more effectively than noncoding chromosomes.

Fitness function

The fitness value of each chromosome has been calculated by solving the corresponding problem.

Selection operator

The requirement parents for using of crossover have been obtained by one of the five selection method, Deterministic Sampling (A), Random Sampling (B), Roulette Wheel (C), Ranking (D) andTournament(E).

Crossover operation and mutation operator

Several crossover operators have been proposed in reference [29]. Similar job two point crossover has been used in this research. In order to produce small perturbations on chromosomes to promote diversity of the population, a shift mutation operator has been used in this article.Crossover and mutation probability must be determined during parameters calibration.

Population replacement

Chromosomes for the next generation are selectedfrom the enlarged population. The best pop_sizechromosomes of the enlarged population have beenselected for the next generation.

Termination criterion

The algorithm must terminate according to a criterion. This criterion is specified by reaching to maximum number of iteration *it_max*.

4. IMPERIALIST COMPETITIVE ALGORITHM

ICA is a novel population-based evolutionary algorithm proposed by Atashpaz-Gargari and Lucas [15]. The ICA initiates with an initial population, like most evolutionary algorithms. Each individual of the population is called a 'country' equivalent 'chromosome' in GA. Some of the most powerful countries are chosen to be the imperialiststates and the other countries constitute the colonies of theseimperialists. All the colonies of initial countries are partitioned among the mentioned imperialists based on theirpower. Equivalent of fitness value in the GA, the power ofeach country, is conversely proportional to its cost. Anempire is constituted from the imperialist states with theircolonies [30].

After all empires were formed, the competition between countries starts. First, the colonies in each of empires start moving toward their imperialist. During this movement, if the colony gets better cost function than its imperialist does, they will exchange their positions and the algorithm will continue with the new imperialist. The power of each empire is calculated by imperialist cost function and colonies. The empire which is weaker than the others loses its colonies. Each imperialist attempts to gain the colonies of other empires. The most powerful empires have a more chance to gain the colonies from the weakest empires. The more powerful an empire is, the more likely it will possess the weakest colony of the weakest empire (Imperialistic competition)

During the competition weak imperialists will lose their weakest colony gradually. When an empire loses all of its colonies, it will be eliminated from the population. In fact the empire collapses. The final level of imperialist rivalry is when there is only one empire in the world. The main steps of ICA are described as follows:

Step 1 Generating of Initial countries

Each individual of the population is called a 'country' equivalent 'chromosome' in GA. Each country denotes a socio-political characteristic in that country such as culture, language, business, economic policy and etc. The socio-political characteristic in countries is the same different type of variables. There are two different types of variables, continuous variables (x, q, I^+, I^-) and binary variables (y). Each country consists of five variables, $x, q, I^+, I^-$and y where all of these variables must be optimized.

Initial values of continuous variables are generated randomly by uniform distribution function. To generate initial value for binary variable, we use a simple and effective heuristic which has been presented by Mohammadi et al. [27].

Step 2 Generating of Initial imperials

A set of the most powerful countries form imperialists and the rest weaker countries are colonies of imperialists. The power of each country is calculated based on the objective function.

Step 3 Assimilation of colonies

Assimilation has been modeled by moving all the colonies toward the imperialist. Each country (colony) has different socio-political characteristics (variables), so every socio-political characteristic (variables) could moves toward the related socio-political of imperialist in different ways. Continuous variables of colonies move toward related continuous variables of its imperialist and binary variables move toward binary variables of its imperialist.

The assimilation of continuous variables is modeled by moving the colony toward the imperialist by *x*units $x \sim U(0, \beta \times d)$. Where $\beta > 1$and$\theta \sim U(-\gamma, \gamma)$. $d$is distance between colony and the its imperialist.

The movement of binary variables is accomplished by crossover operation, like crossover operator in genetic algorithms. Crossover allows exchanging information between different solutions (chromosomes) so it is useful to assimilate binary variables.

Step 4 Revolution

The revolution increases the exploration of the algorithm and prevents the early convergence of countries to local minimums. A very high value of revolution decreases the exploitation power of algorithm and can reduce its convergence rate [31].In each iteration, some of the colonies are chosen and their positions are exchanged. This mechanism is similar to mutation process in genetic algorithm for

creatingdiversification in solutions. Mutation increases the variety in the population, so this operator is used for creating a revolution in binary variables.

Step 5 Exchange the colony with imperialist

During assimilation and revolution, a colony may get to a situation with lower cost than the imperialist. In this case, the imperialist and the colony change their positions.

Step 6 Imperialistic competition

To start the competition, after selecting the weakest colony, the possession probability of each empire must be found. The normalized total cost of an empire is simply obtained by

$$NTC_n = TC_n - \max\{TC_i\}$$

Where, $NTC_n$and TC_n are the total cost and the normalized total cost of nth empire, respectively.

The total power of an empire is mainly contributed by the power of imperialist country. It is clear that the power of an empire includes the imperialist power and their colonies.

$$TC_n = cost\{imperialist_n\}C + \rho * mean\{cost(colonies\ of\ empire_n)\}$$

Where ρ is a positive small number.The possession probability of each empire is given by

$$p_{p_n} = \left| \frac{NTC_n}{\sum_{i=1}^{N_{imp}} NTC_i} \right|$$

Roulette wheel method was used for assigning the mentioned colony to empires.

Step 7 Elimination of powerless empires.

During the competition weak imperialists will lose their weakest colony gradually. When an empire loses all of its colonies, it collapses. At the end just one imperialist will remain. This is the optimum point.

Step 8 Stop criterion

In such an ideal new world, all the colonies will have the same positions and same costs and they will be controlled by an imperialist with the same position and cost as themselves. In such a world, there is no difference not only among colonies, but also between colonies and imperialist [32]in this situation; the algorithm has reached the global solution.

Stopping criterion in proposed algorithm is to get the maximum decades (maximum iteration).

5.PARAMETER CALIBRATION AND COMPUTATIONAL TESTING

Parametercalibration andcomputationalexperiments are key steps in the developmentof any algorithm.Conventionally, setting parameters relies on a trial and-error procedure. However, this procedure cannot determine optimal parameter settings and consumes considerable time [33]. In this paper, we employed the Taguchi Methodology to optimize the parameters of the algorithms via systematic experiments.

5.1. Parameter calibration

Taguchi [34] developed a family of fractional factorial experiment (FFE) matrices that ultimately lessens the number of experiments, but still provides adequate information. Full fractional experiment is not an effective approach when the number of factors becomes large, so in our case because of the large number of factors and few levels for each factor we use Taguchi method to calibrate the parameters.

A transformation of the repetition data is created toanother value by Taguchi which is the measure of variation. The transformation is the signal-to-noise (S/N) ratio. The S/N ratio is obtained by following equation:

$$\frac{S}{N}\ ratio = -10\log(objective\ fnction)^2$$

Where “signal” describes the desirable value, in our study we use the following performance measure as desirable value.

$$\left(\left(\sum_{i=1}^{15} Metaheuristic_{sol_i} - LB_i \Big/ LB_i \right) \times 100 \right) \Big/ 15$$

Where $Metaheuristic_{sol_i}$ is the obtained solution by the algorithm (GA or ICA) and LB_i is the solution obtained by the lower bound. Note that each problem runs 15 times and the average of this runs consider as corresponding desirable value for the problem. It is obvious that the smaller value of the performance measurement shows that the metaheuristic is more efficient.

The term “noise” specifies the undesirable value (standard deviation). The S/N ratioindicates the amount of variation present in the response variable. Here, maximization of the signal-to-noise ratio isdesirable (i.e., is the goal).

In order to calibrate the parameters of the algorithms we determine the level of each parameter. Table 1 shows the level of each parameter for two metaheuristics. Since increase in number of products (N) leads to polynomial increase in computational timeso that to make a fair calibration, we divide number of population and maximum iteration bynumber of products (N).

Table 1. Factor levels

	Parameter Level	Level 1	Level 2	Level 3	Level 4	Level 5
GA	Selection Type	A	B	C	D	E
	Crossover Probability	0.1	0.2	0.3	0.4	.5
	Mutation Probability	0.05	.10	.15	.20	.25
	Number of Population	500/N	600/N	750/N	900/N	1000/N
	Maximum Iteration	500/N	600/N	750/N	900/N	1000/N
ICA	Number of Population	500/N	600/N	750/N	900/N	1000/N
	Number of Imperialist	5	7	10	12	15
	Maximum Iteration	0.5	0.7	1	1.2	1.5
	Revolution Probability	500/N	600/N	750/N	900/N	1000/N
	ρ	0.1	0.2	0.3	0.4	0.5

In this case, Taguchi method needs 25 experiments for each algorithm.As mentioned above, for each 25 experiment 15 independent runs are carried. The termination criterion of maximum elapsed CPU time ist=7200S [9]The required parameters for these problems are extracted from the following uniform distributions:$c \approx U(5,10), d \approx U(0.5,1), h^{+} \approx U(0.05,0.1), h^{-} \approx U(1,5), b \approx U(0.02,0.04), p \approx U(0.02,0.04), s \approx U(100,1100)$

In order to conduct the experiments, we implemented GA and ICA examples in MATLAB run on a PC with a 2.27 GHz Intel Core i5 processor and 3 GB RAM memory and analyzed the result by Minitab 16 software.Figure2 and 3 show the average S/N ratio obtained at each level for ICA and GA.

According to Figure 2 and Figure 3 the optimal levels of factors have been indicated in Table 2.

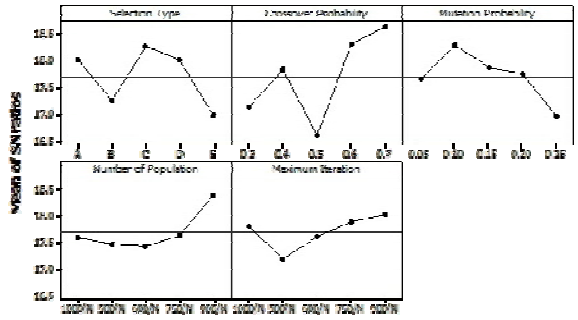

Figure 2. Main effect plot for S/N ratios for GA

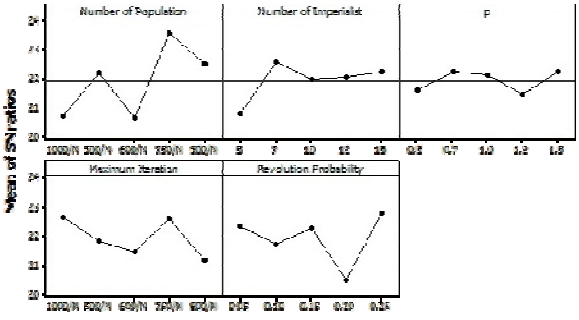

Figure 3. Main effect plot for S/N ratios for ICA

Table 2. The optimal levels of factors

	Parameter Level	Optimum
GA	Selection Type	C
	Crossover Probability	0.7
	Mutation Probability	0.10
	Number of Population	900/N
	Maximum Iteration	900/N
ICA	Number of Population	750/N
	Number of Imperialist	7
	Maximum Iteration	750/N
	Revolution Probability	0.25
	ρ	0.7

5.2. Comparison of the algorithms

In this section, in order to evaluate and compare the performance of two proposed, we consider different problem sizes.

For each problem set, 15 independent instances are randomly generated (225 problems) and the required parameters for these problems are extracted from the following uniform distributions:

$$c \approx U(5,10), d \approx U(0.5,1), h^{+} \approx U(0.05,0.1), h^{-} \approx U(1,5), b \approx U(0.02,0.04), p \approx U(0.02,0.04), s \approx U(100,1100)$$

For each of the 15 instances, 15 independent runs are carried out for each algorithm within a reasonable CPU time, 7200 s.We obtain the mean of 15 instances as the response variable

of each instance. This response is used to compare two algorithms. Problems have been solved in MATLAB run on a PC with a 2.27 GHz Intel Core i5 processor and 3 GB RAM memory.The computed results are reported in Table 3.

Table 3. Computational results

Problem set	Dimension of problems ($N \times M \times T$)	GA	ICA
1	$2 \times 2 \times 2$	16.72%	9.66%
2	$3 \times 3 \times 3$	16.76%	9.42%
3	$4 \times 4 \times 4$	9.38%	6.46%
4	$5 \times 5 \times 5$	15.01%	11.69%
5	$6 \times 6 \times 6$	15.02%	8.55%
6	$7 \times 7 \times 7$	15.84%	7.48%

7	8 × 8 × 8	14.85%	10.07%
8	9 × 9 × 9	13.71%	9.20%
9	10 × 10 × 10	14.04%	10.12%
10	11 × 11 × 11	10.95%	6.97%
11	12 × 12 × 12	10.32%	6.60%
12	13 × 13 × 13	12.17%	6.92%
13	14 × 14 × 14	11.76%	8.99%
14	15 × 15 × 15	13.41%	8.58%
15	16 × 16 × 16	15.08%	8.07%

We are now employing a 95% confidence level and we are using Tukey HSD confidence intervals to compare algorithms with Minitab 16 Software. The result has been showed in Figure 4. From the Figure 4 it is clear that the proposed ICA algorithm is statistically better than the proposed GA algorithm.

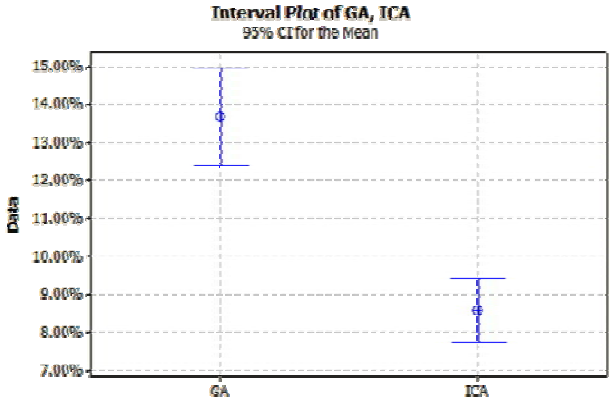

Figure 4:Tukey HSD confidence intervals

6. CONCLUSION

This paper studies the permutation flow shop lo sizing and scheduling problem and developed a new model for the problem under sequence-dependent and carryover setups with considering backlogging.

To solve the problem, two metaheuristics was proposed namely, GA and ICA. Since the parameters of any algorithm has significant effect onalgorithms performance, we use a fractional factorial experiment namely, Taguchi method. In order to evaluate the effectiveness and robustness of the proposed GA and ICA, we carried out a comparison between the algorithms. In this context, we presenteda lower bound and compared the algorithms against it. The distance betweenthe algorithms and the lower bound was calculated. Base on the results, Tukey HSD confidence intervals was employed to determine which algorithm is statistically superior to the other one. The results showed the ICA outperforms the GA.

As a direction for future research, it would be interesting to develop other metaheuristic, like Particle Swarm Optimization, Harmony Search and Honey Bee Algorithm. As an additional contribution, developing of the single objective into multi objective models can be considered.

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International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

RESEARCH ON INDUCTION HEATING - A REVIEW

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Abstract: This paper presents results of finite element analysis of induction heating problems considering temperature dependence of material characteristics. In this analysis, we have used the three-dimensional finite element method in order to correctly express induction heating coil's shapes and to make clear its effects on temperature distributions. The heat-conducting problem and the eddy current problem are coupled, and solved by using the step-by-step calculations.

Keywords: Magnetic field, Open-type magnetizer, Toroidal

1. INTRODUCTION

In the conventional finite element analysis for linear induction heating problems, magnetic material parameters are usually assumed to be constants with respect to temperature. As for the non-linear analysis, the temperature dependence of the electrical conductivity is easily taken into consideration; however, the temperature dependence of the magnetic permeability is usually neglected due to its difficulty because there are no catalog data concerned on temperature dependence of the magnetic permeability and such properties are very difficult to measure [1-3].

In the designing of induction heating devices, we should measure and consider the dependence of the magnetic permeability to obtain more accurate solutions. Generally the permeability is measured under a constant magnetic field condition with toroidal cores because the magnetic field strength directly proportional to the exciting current. Disadvantage of this measuring method is that it takes long time in making toroidal cores and those windings.

On the other hand, the magnetic flux density is directly obtained from the magnetic vector potential distributions in the case of the finite element analysis. The magnetic field strength is obtained finally from the magnetic flux density value and the magnetic permeability value in each element with the constitutive relation.

Therefore, it is very convenient to use the relationship between the magnetic flux density, the magnetic permeability and temperature as a function in the numerical computations. In this paper, such functions of the magnetic permeability at any temperature under constant flux density conditions are derived from the measured data. The numerical analysis considering the temperature dependence of the permeability give us more important knowledge in designing modern induction heating devices.

2. MATERIAL CHARACTERISTICS[4]

Conventionally, we have measured the temperature dependence of the magnetic permeability by using toroidal cores and platinum exciting coils and pickup coils as shown in Fig. 1, in order to realize a high temperature condition. The platinum wires are used to prevent melting metal.

Fig. 1 ring sample

However, it needs a long preparing time to change specimen in a ring-type core because it is necessary to renew the windings and reconnect the platinum wires with the terminals for taking out the pickup signals from the vacuum chamber [2-3]. Fig. 2 shows a newly developed open-type magnetizer. The magnetic properties of a ribbon specimen can be measured by only inserting it through the quartz holder, which has the fixed exciting coil and the pickup coil.

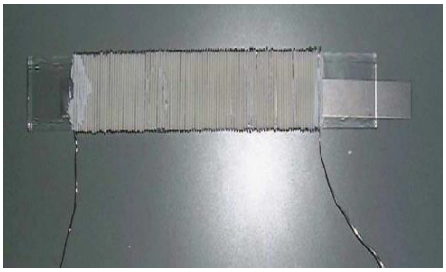


Fig. 2 Magnetizer for a plate sample

The numbers of windings of the exciting coil and the pickup coil are 150 turns and 16 turns, respectively. The alumina pipes were used in insulation of the windings. In the verification of this measuring apparatus, a SS400 sample was measured. In the measurement, the exciting frequency was changed from 100 Hz to 100 kHz with a B–H analyzer, and the field strength was also changed to be from 200 A/m to 1600 A/m. Figs. 3 and 4 show the measured hysteresis loci when the exciting frequency is 100 Hz and 100 kHz,

respectively. In these figures, the loop measured with the new open-type magnetizer was compared with the conventional one. There were good agreements between the results obtained with each magnetizer in high-frequency exciting condition (see Fig. 4) [4].

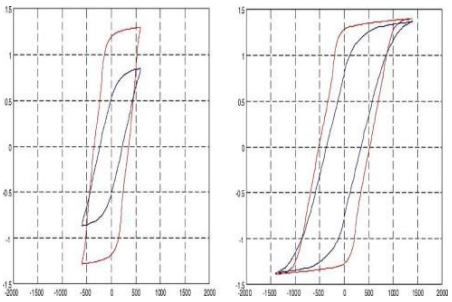


Fig. 3 the measured data of B–H curve at 100 Hz (H-constant)

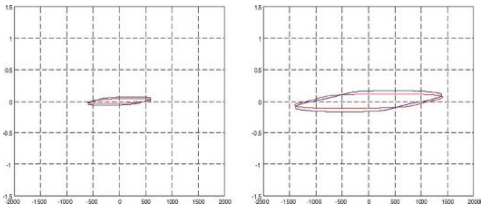


Fig. 4 the measured data of B–H curve at 100 kHz (H-constant)

It can be said that the simplified open-type magnetizer is useful in measuring many sample sheets under high frequency conditions during a short term of measurement. Since the purpose of this measurement is to obtain the data depending on temperature, which is applied to the non-linear magnetic field and thermal conducting analysis. Fig. 5 shows the measurement system. As shown in this figure, the specimen placed in the quartz vacuum chamber is being heated by the infrared ray heating device. The temperature of specimen was measured with a platinum–rhodium thermo couple and the temperature was controlled with the personal computer (PC) and the program controller. The B–H analyzer was used for the measurement of the magnetic properties. The specimen used in this measurement was SUS430. In the measurements, the exciting frequency was changed from 100 Hz to 500 kHz, and the magnetic field intensity was changed from 50 A/m to 800 A/m. Figs. 6 and 7 show the measured results for 100 kHz and 100 kHz, respectively. As shown in these figures, the magnetic permeability can be expressed as a function of the temperature and the magnetic flux density (a) (ortho magnetic field strength (b)).

The permeability changed quickly around the Curie point. Because the large exciting power needed to input in high-frequency measurements, it was difficult to obtain the data in the saturation region of the magnetization. To obtain such data at a high-frequency used in numerical computations, we used an approximation with the following function [5].

$$\sum_{i=0}^{n} \begin{bmatrix} n \\ i \end{bmatrix} p_i \cdot t^i (1-t)^{n-i} \qquad (1)$$

Where, (n, i) is the combine parameter, which can be derived as a coefficient when (a + b) n is expanded in progression.

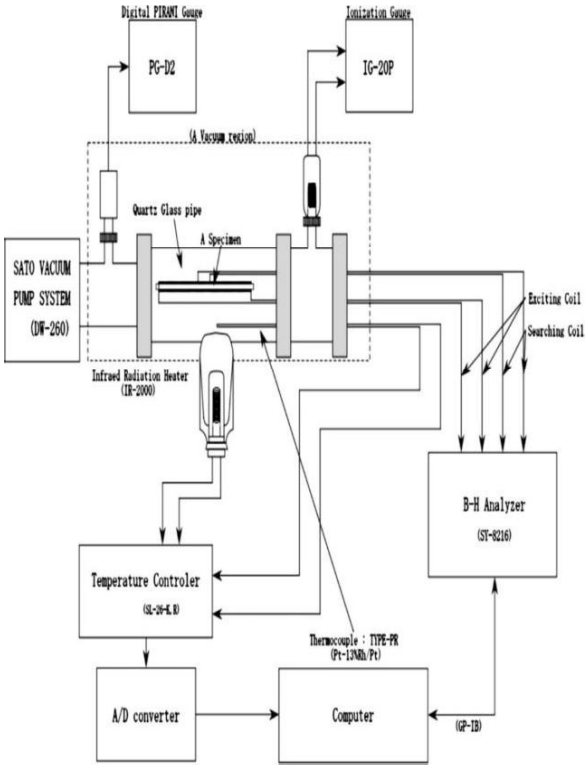
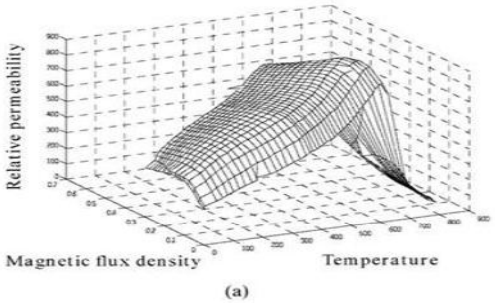


Fig. 5 The measurement system for the property depending on temperature (a) B-constant and (b) H-constant



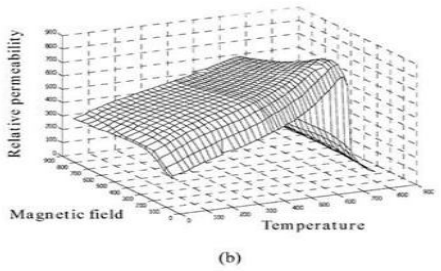
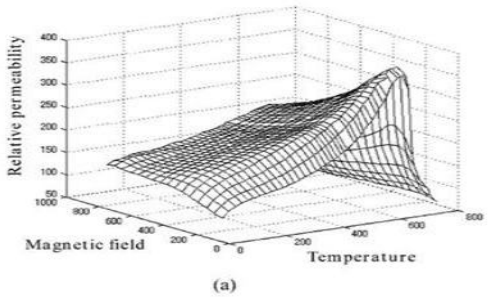


Fig. 6 Three-dimensional distribution of relative permeability at 10 kHz (a) B-constant and (b) H-constant



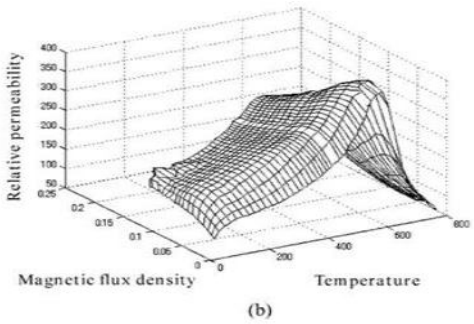


Fig. 7 Three-dimensional distribution of relative permeabilityat 100 kHz. (a) B-constant and (b) H-constant

3. FORMULATION[9]:

The three-dimensional finite element equation with the edge element is given as follows.

$$G_i = \int_V \mathrm{rot}\, \boldsymbol{N}_i \cdot (\nu\, \mathrm{rot}\, \boldsymbol{A})\mathrm{d}V - \int_V N_i \cdot \boldsymbol{J}_0 \mathrm{d}V + \int_V N_i \cdot \sigma \left(\frac{\partial \boldsymbol{A}}{\partial t} + \mathrm{grad}\phi \right) \mathrm{d}V = 0 \quad (2)$$

Where, A is the magnetic vector potential, J_0 the exciting current density, σ the electrical conductivity and N_i is the vector interpolation function of the tetrahedral element. N_i can be written as,

$$N_i = \lambda_{me}\mathrm{grad}\lambda_{ne} - \lambda_{ne}\mathrm{grad}\lambda_{me} \quad (3)$$

Where, λ is the volume coordinate at node. The governing equation of the transient heat problem is written as,

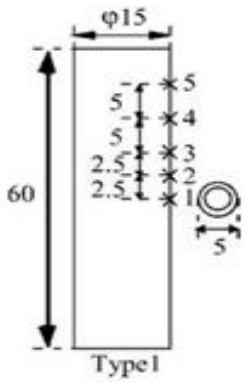


Fig. 8 Structure of model (Type-1)

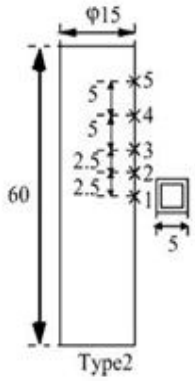


Fig. 9 Structure of model (Type-2)

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\lambda_x \frac{\partial T}{\partial t}\right) + \frac{\partial}{\partial y}\left(\lambda_y \frac{\partial T}{\partial t}\right) + \frac{\partial}{\partial z}\left(\lambda_z \frac{\partial T}{\partial t}\right) + Q \quad (4)$$

Where, ρ is the density, c the specific heat and Q is the quantity of heat.

4. RESULTS AND DISCUSSIONS[6-8]:

The three-dimensional finite element analysis was carried out by taking into account of the temperature dependence of the material properties. Figs. 8 and 9 show the models used in the analysis and measurement. We have used three models; however we show here two typical cases.

The cross-points indicated on the conductor surface are measured points with thermo couple. The Type-1 has a circular cross section of the induction coil and Type-2 has a square cross section. Figs. 10 and 11 show the calculated flux distributions and the comparison of the calculated temperature on the conductor surface with the measured ones. There was a good agreement between the measured and calculated results. It was evident that the flux did not go through inside of the heating conductor due to the skin effect.

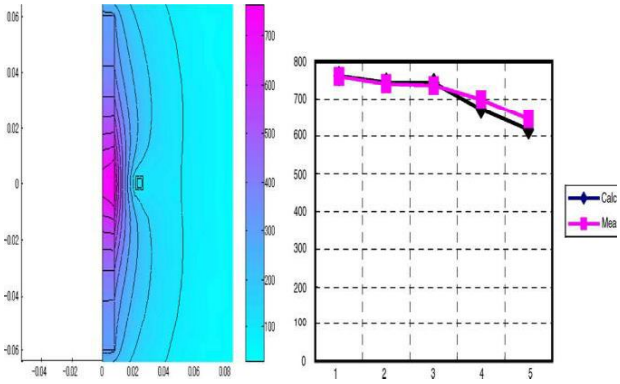


Fig. 10 Temperature distribution for Type-1

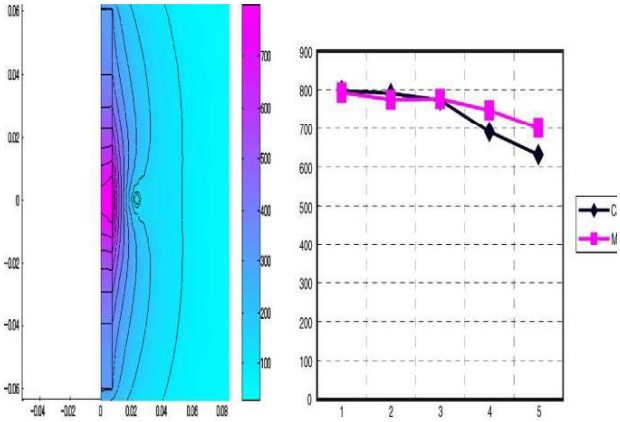


Fig. 11 Temperature distribution for Type-2

5. CONCLUSION:

The results obtained in this work can be summarized as follows [10]:

(1) In this paper, the new simplified open-type magnetizer has been presented in order to reduce measuring time. The measurement by using the new magnetizer can be performed by only changing a ribbon sample inside. Accurate measured results similar to the toroidal core type were able to be obtained under high-frequency conditions.

(2) In the measurements, the magnetic permeability in material has been measured as a function of the temperature and the exciting frequency (including eddy Current effect). Those characteristics were made clear for the SUS340 specimen.

(3) In the verification, the three-dimensional finite element method was applied to the simple induction heating models and the calculated results were compared with the measured ones. The measured data mentioned in the above was used in the measurement and we obtained the good agreement between the measured and calculated results.

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International Journal of Science and Engineering Applications
Volume 2 Issue 6, 2013, ISSN-2319-7560 (Online)

Preventing SQL-Based Attacks Using Intrusion Detection System

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Abstract: With the advancement of technology everyone is using computer and web applications. These web applications can be easily made by using rapid application development environments by developers. But they do not consider security aspect necessary in the process of providing attractive functionalities & also they are not experts in that field. This make web applications vulnerable to several attacks. Among these attacks SQL injection is considered most dangerous vulnerability. This paper describes various approaches used by authors to prevent SQL injection attack using various methods like intrusion detection, black box testing etc.

Keywords: SQL injection, Intrusion detection, anomaly detection, misuse detection

1. INTRODUCTION

Web applications are very popular today. The developers of the web applications are focused more towards adding the best possible functionalities. In this due course they often neglect security issues. Many tools have been developed to detect Web application vulnerabilities but hackers are still successfully exploiting Web applications. A possible reason is that most tools just scan Web application vulnerabilities, but few tools can automatically revise these vulnerabilities [5].

The user send request via a web browser in the form of URL, that is converted into an IP address, to the web server. Web server converts these requests to SQL commands. The result of these commands generate the response for user for the final presentation. Some rapid application development environments lead to good functionalities with vulnerabilities. These developers are not the security experts so they cannot provide security measures [1].

Nowadays, web applications are vulnerable to many attacks and injecting commands is in the top of this list [2]. Traditional network-based firewall systems offer no protection against these attacks, as the malicious (fractions of) SQL or tampered requests are located at the application layer and thus are not visible to most of these systems [3].Web-based applications are implemented using a number of server-side executable components, such as CGI programs and HTML-embedded scripting code, that access back-end systems, such as databases [4].Existing prevention systems are often insufficient to protect this class of applications, because the security mechanisms provided are either not well understood or simply disabled by the web developers "to get the job done [4]." In SQL, character constants are surrounded by apostrophes (‘), semicolons (;) usually separate statements, and (--) start of comment, so the mischievous inputs will usually include at least one of those characters [6]. Typical Intrusion detection systems can prevent the use of some common malicious strings like "union", "or 1=1" [1]. Moreover they are considered as authorized users commands in databases security measures. Some SQL based attacks define earlier in [4] are as follows:

- **SQL injection**: Typing SQL keywords and control signs an intruder is able to change the structure of SQL query developed by a Web designer. Here the structure of SQL query is changed by the attacker. A query looks like:

```
uname = getAuthenticatedUser()
cctype = getUserInput()
result = sql("SELECT nb FROM creditcards
WHERE user='"
+ uname + "' AND type='" + cctype +"';")
print(result)
```

The changed query structure will be executed and database will be affected as the attacker requires.

- **Cross site scripting (XSS):** The attacker injects a script and tries to destroy relationship between web browser and web server. This script is not controlled by attacker once injected. They focus on stealing information that is

- sensitive for user like credit card details. Malicious JavaScript programs can take advantage of the fact that they are executed in a foreign environment that contains sensitive information [4].

- **Other data centric attacks:** This class focuses on particular actions taken by attacker on other query constants. If we see xxx usertype then it is considered as attack. Two-step SQL injection attack also comes under this class of attack. Here attacker inserts or deletes a string from the database. The web site periodically deletes inactive users with the following script [4]:

```
old = now() - 3 months
users = sql("SELECT uname FROM users
WHERE last_login < "+old+";")
for u in users:
sql("DELETE FROM users WHERE uname='" +
u
```

These are some attacks which are SQL based. In this paper we are going to discuss work carried by authors for preventing malicious SQL injection attacks in different years and best possible to our knowledge we have mentioned some drawbacks. Several intrusion detection techniques are introduced along with them we will also discuss other techniques used to prevent these attacks.

2. LITERATURE SURVEY

Fonseca et al. [1] proposed an intrusion detection system (IDS) at database level. This IDS is based on anomaly detection technique and detects the database operations that are malicious. According to them it is best to place a layer at database level which will be an additional layer for intrusion detection. The purpose served here will be the detection of insider attacks and malicious SQL attacks. They had done an offline analysis. The proposed architecture in [1] is:

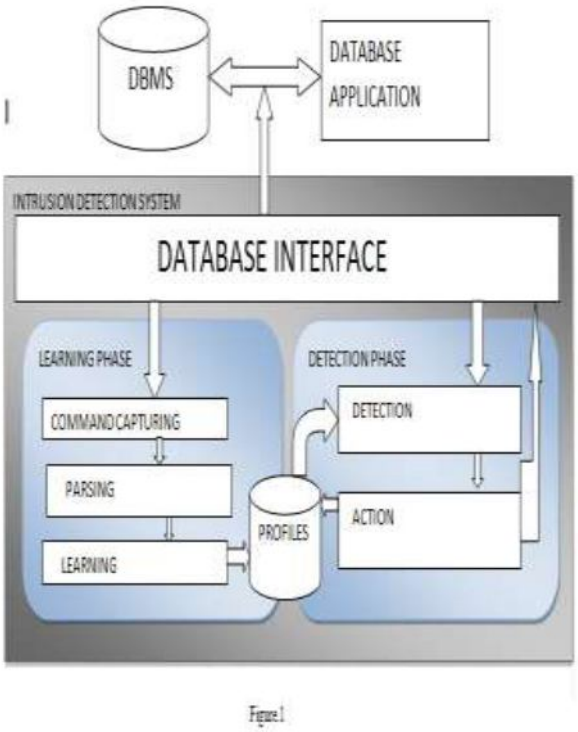

Figure 1

Bockermann et al. [3] proposed technique that used machine learning algorithm 'internal self' organizing maps' to detect the malicious behavior. The approach incorporates the parse tree structure of SQL queries as characteristic e.g. for correlating SQL queries with applications and distinguishing benign and malicious queries [3]. This paper followed the approach used in [7]:

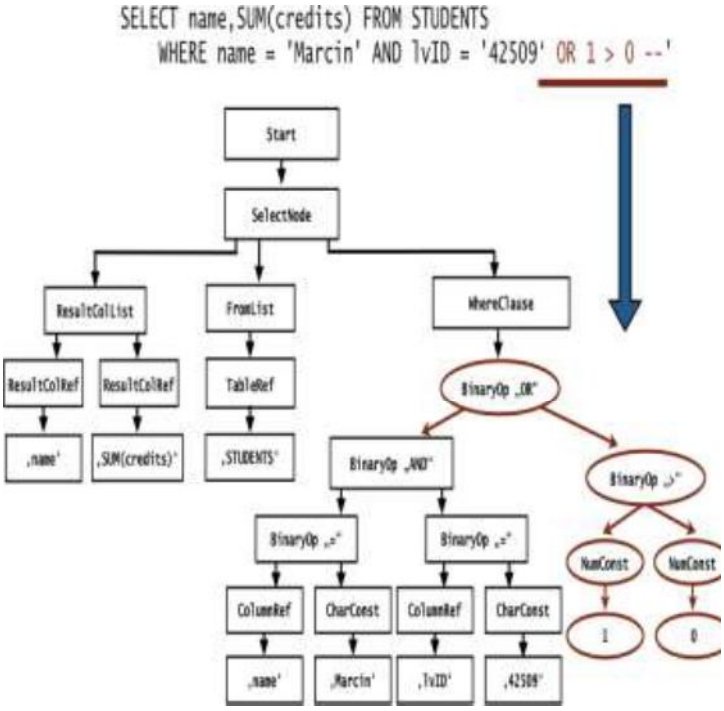

Figure.2

If the query matches the above diagrammatic representation then it is normal behavior else it will be considered malicious behavior. They used Apache Derby database & generated off a grammar file using tools javacc giving description of grammar. They collected data of the popular Typo3 content management system, create a set of different queries & added attacks that closely relate to SQL injections.

The detection rate was considered as TPR and false positives as FPR. Tree-Kernels were used for SQL grammars & query analysis. Typo3 were represented by dots and malicious modifications as squares. This resulted into highly structured query language, high detection rates and speed.

The author mentioned the drawback here as computational-overhead as computation of kernel matrix took a few more time than necessary. This was due to use of tree-kernel approach.

Pinzon et al. [8] used case based reasoning (CBR) engine which is collaboration of advanced algorithms that can easily allow classification of malicious codes. The agent used here is named as CBRid4SQL. Here combination of CBR system, artificial neural network (ANN) & support vector machine (SVM) gave advantage of learning and adaption and query detection ion best possible way.

CBR related SQL query has three steps namely ; problem description, solution for performing some action & final state after solution. The steps retrieval, reuse, revise, retain were steps followed where main learning phase was completed and machine learning algorithm were used.

Method		Method		Method	
BayesNet	638	Naive Bayes	666	AdaBoostM1	665
Bagging	684	DecisionStump	598	J48	689
JRIP	692	LMT	693	Logistic	688
LogitBoost	680	MultiBoostAB	666	OneR	622
SMO	685	Stacking	437	CBRid4SQL	**698**

Table 1. Performance of different classifiers

This table 1 shows that the highest-performance system is CBRid4SQL, which has a success rate of 698/705 [8]. The proposed agent is capable of low error rates compared to other existing systems of that time, robustness, decision mechanism and flexibility in queries review.

Valeur et al. [4] focused on mimicry based SQL attacks by developing anomaly based system. The tool can be deployed on a host that contains custom-developed server-side programs and are able to automatically derive models of the manner in which these programs access a back-end database [4]. Here profiles for normal databases access are developed and models are obtained during training phase. The anomalies are detected by the help of profiles made earlier in detection phase.

They used several models in order to characterize the normal behavior of web applications for mimicry attacks. Training phase is divided into data feeding of models for profile building process and anomaly score calculation. If an anomaly score exceeds the maximum anomaly score seen during training by a certain tunable percentage, the query is considered anomalous and an alert is generated. This anomaly based detector had less false positives and little overhead.

Skaruz et al. [9] used recurrent neural network (RNN) which was trained by back propagation time algorithm (BPTT). They divided SQL queries statements into tokens. In training phase, activations of all neurons are computed. Next, an error of each neuron is calculated. These steps are repeated until last token has been presented to the network [9].

They took different tokens and defined their indexes in table 2 [9] as follows:

They used datasets as DATASET I AND DATASET II. The second dataset showed the scope of use of re-

evaluated data. This division of statements into tokens led to clear line of distinction between an attack and a authorized statement.

Skaruz et al. [10] in 2010, used neural networks to detect SQL attacks and gene expression programming (GEP).jut like they did earlier this time also they divided SQL problem to time series prediction and classification problem. The statement of SQl were again divided into tokens and RNN was used and trained by BPTT.

Each data subset had a corresponding network. The trained network was examined for both attacks and normal SQL queries. They evaluated 2 coefficients that were used as threshold for RNN output. They used two approaches that is RNN and GEP for detection of SQL based attacks. RNN with classification rules is able to predict sequences of 10 tokens with false alarms rate below 1%. We also showed how the number of SQL queries used for setting the coefficients affects the number of false alarms. Classification accuracy received from GEP depicts great efficiency for SQL queries constituted from 10 to 15 tokens. For longer statements the averaged FP and FN equals to about 23%. [10]

Lee et al. [11] provided a framework and named it as DIDAFIT (detecting intrusions through fingerprinting transactions). This system consists of known fingerprints that are compared to every database access and hence fate it as intrusive or normal activity. DIDAFIT is a database intrusion detection system that identifies anomalous database accesses by matching database transactions with a set of legitimate transaction fingerprints. This is database IDS at application level. It can also be be classified as misuse –signature based IDS. This technique deals best with incomplete training datasets and has lower false negatives rate.
This framework deduces the missed SQL fingerprints, the statements were easily converted into fingerprints, high risk SQL statements were detected in training sets.

The framework of proposed system is as follows:

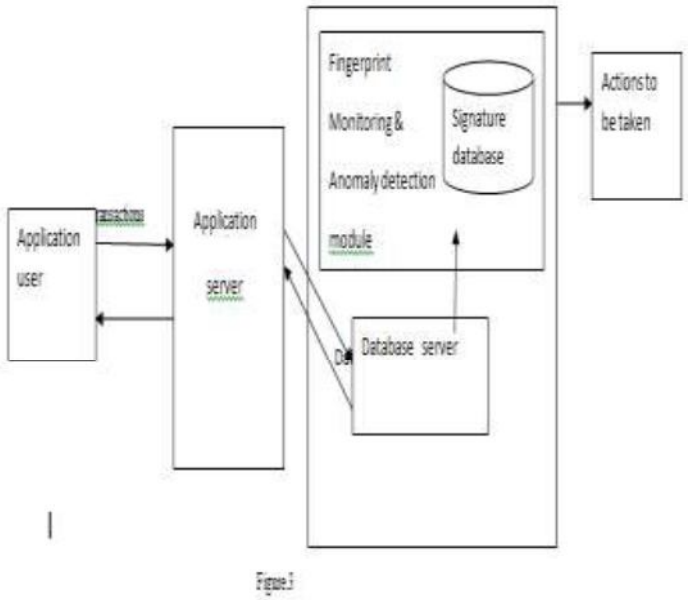

Figure 1

But not to forget that every misuse anomaly detection has drawback that it cannot detect new attacks as no existing fingerprint will match the attack and system will be left vulnerable.
Kiani et al. [12], used an anomaly detection approach. They called the model as same character comparison (SCC) model where HTTP request's section were divided on the basis of character. It follows the approach of FCD (frequency character distribution) model and tried to overcome its limitation. For example, given the extracted query section 'id=444', the frequency count for the characters would be 3 for the character '4', and the frequency count would be 1 for the characters 'i', 'd', '=', and zero for all other characters. Here query section is taken from HTTP requests directly [12].
In training phase frequency is evaluated. The cumulative characteristic count is calculated after all requests are processed. Expected values are evaluated then. In testing phase, anomaly score is calculated using Chi-square test and threshold is determined. This threshold decides whether SQl query is a intrusive one or not. If anomaly score is above the threshold defined alert is triggered.
The approach operates by parsing the query section of HTTP requests and creates profiles for each file. It requires no access to the source code, or modification of existing software modules [12]. Moreover large training datasets were used. Here we got reduced false alerts, no user interaction and UNION attacks and tautology attacks were detected.

Aswami et al [13] proposed the architecture given below:

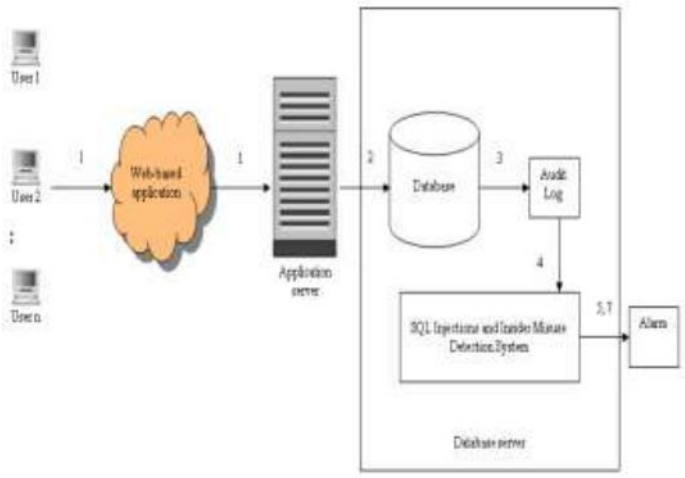

Figure.4

This paper proposes a system that will detect both insider attack and SQL injection attack. It is names as SIIDMS (SQL injection and insider misuse detection system) architecture. This paper has presented a description on the threats in database security and the intrusions from both external and internal attacks against database systems [13]. This is because in many instances, the insiders do have authorized access to their database system but often misuse their rights.

Razzaq et al. [14] introduced the defense mechanism for application level. They provided multi layered defense mechanism capable of detecting both classes of known and unknown attacks. They showed results for high detection rate and low false positives using graphical representation. They focused on XSS attacks and SQL injections. System is evaluated against the existing data mining techniques, attribute length, character distribution, or inference structure used by different models in anomaly detection [14]. First layer, filter out the special tags from malicious input through Filter. Second layer, *Detection module* detects malicious input through positive, negative and anomaly components and lastly syntactical and semantically validation through Analyzer & Validation module [14].

Ciampa et al. [15] proposed a tool named V1p3R.Unlike other exsisting tools it didn't generate SQL queries rather it performed penetration testing. The proposed approach worked on following steps for a web application:

- It determined hyperlinks structure & its input forms
- It was seeded with already known SQL attacks for reporting error(Standard attacks consist in a set of query strings that are not dependent on the Web application.[15])
- Then every access to web application is compared to regular expressions in the database related to error messages.
- It continues the attack using text mined from the error messages with the objective of identifying likely table of field names, until it is able to retrieve (part of) the database structure[15].

This approach worked out for 12 real web applications in different fields.

Boyd et al. [16] used one of the Instruction-Set Randomization application. To create complications for attacker, the SQL standard keywords are appended with a random integer. Therefore, any malicious user attempting an SQL injection attack would be thwarted, for the user input inserted into the "randomized" query would always be classified as a set of non-keywords, resulting in an invalid expression.

They called it SQLrand system and its architecture is given as:

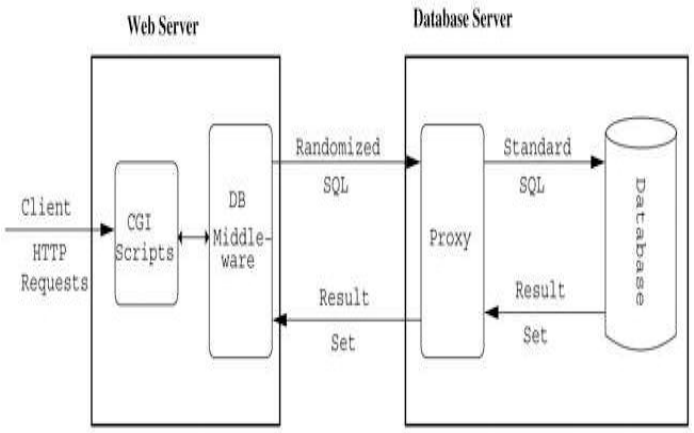

Figure.5

3. CONCLUSIONS AND FUTURE WORK

This work is carried out for details in intrusion detection and SQL based attacks. This result will help for database and IDS work together. This contains work since 2002 to 2011 with some drawbacks and advantages suggested. Including SQL injection we have discussed about some XSS attacks and mimicry attacks. This paper will help

people looking forward to perform research work in IDS and SQl based attacks field.

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