ABSTRACT

The majority of industrial applications of machining are in metals. Although the metal cutting process has resisted theoretical analysis because of its complexity, the application of these processes in the industrial world is widespread. Machining processes are performed on a wide variety of machine tools.

Metal cutting processes can be viewed as consisting of independent input variables, dependent variables, and independent-dependent interactions or relationships. The engineer or machine tool operator has direct control over the input variables and can specify or select them when setting up the machining process.

Turning is a machining process for generating external surfaces of revolution by the action of a cutting tool on a rotating work piece, usually in a lathe. Turning is the major operation in a machining sequence discussing in this research work.

A lathe is a machine tool which rotates the work piece on its axis to perform various operations such as cutting, knurling, drilling, thread cutting etc. with tools that are applied to the work piece to create an object which has symmetry about an axis of rotation. Lathes are used in wood turning, metal working, metal spinning, Thermal spraying, parts reclamation, and glass-working.

Aluminium alloys can be machined rapidly and economically. Because of their complex metallurgical structure, their machining characteristics are superior to those of pure aluminium. The micro-constituents present in aluminium alloys have important effects on machining characteristics.

The literature survey indicates that, in machinability studies investigations, statistical design of experiments are used quite extensively. Statistical design of experiments refers to the
process of planning the experiment so that the appropriate data can be analysed by statistical methods, resulting in valid and objective conclusions. Design and methods such as factorial design, response surface methodology (RSM) and Taguchi methods are now widely used in place of one-factor-at-a-time experimental approach which is time consuming and exorbitant in cost.

In the literature survey it appears that enough systematic research work has not been carried out regarding machinability of aluminium alloys such as Al6061T6 and Al7075 in different machine environments in dry condition.

In the present investigation it has been carried out systematically to study the effects of all cutting parameters such as feed, cutting speed, depth of cut, tool nose radius and rake angle on machinability factors during turning on aluminium alloys such as Al6061T6 and Al7075 in dry condition. Different machine environments used in the present investigations are medium duty lathe, CNC LT16 XI lathe and MTABXL turner lathe, in dry environment. Experiments are carried out according to design of experiments approach using Taguchi method. L8 orthogonal array is used for medium duty lathe for machining of Al6061T6 and Al7075. L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6. L31 orthogonal array is used for MTABXL turner lathe for machining of Al7075.

Using MINITAB software the mathematical models are developed relating the machinability factors with cutting parameters for different machine environments to predict machinability factors within the scope of the investigation.

The as-received Al6061T6 and Al7075 alloys were used as work piece material to study machinability aspects in the present investigation. The size of both the work pieces used in the present investigation is 25mm diameter and 50 mm length.
Alloy Al6061T6 is one of the most widely used alloys in the 6000 series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics to machinery, equipment applications, recreation products and consumer durables. Alcoa produces Al6061T6 for use in standard, custom shapes, rod, bar products, seamless, structural pipe and tubes.

Al 7075 Aluminium alloy is introduced by Alcoa in 1943, alloy Al 7075 has been the standard workhorse 7XXX series alloy within the aerospace industry ever since. It was the first successful Al-Zn-Mg-Cu high strength alloy using the beneficial effects of the alloying addition of chromium to develop good stress-corrosion cracking resistance in sheet product. Although other 7XXX alloys have since been developed with improved specific properties, alloy Al 7075 remains the baseline with a good balance of properties required for aerospace applications.

Machinability studies of Al6061T6 and Al 7075 two aluminium alloys are conducted by using three lathe machines namely 1. Medium duty lathe machine 2. CNC commercial environment machine 3. MTab XL turn machine.

Design of experiments is carried out according to Taguchi technique. L8 orthogonal array, two level, four factors such as cutting speed, feed rate, depth of cut and nose radius are considered for medium duty lathe, for turning Al6061T6 and Al 7075 in dry condition. L31 orthogonal array, five level, four factors such as cutting speed, feed rate, depth of cut and rake angle are considered for CNC LT16 XI lathe, for turning Al6061T6 in dry condition. L31 orthogonal array, five level, four factors such as cutting speed, feed rate, depth of cut and rake angle are considered for MTABXL turner lathe, for turning Al7075 in dry condition. The single point HSS cutting tool with given nomenclature is used for turning operation.
The surftest SJ-201P profilometer is used to measure the surface roughness. The instrument has a maximum range of -200 \( \mu \text{m} \) to +150 \( \mu \text{m} \) accuracy.

Material removal rate, machining time, machining force and power are calculated using available theoretical relations.

The results obtained in the present investigation are in conformity with the literature survey.

The effects of cutting parameters on surface roughness were carried out for all standardised operational variables as per Taguchi technique.

- L8 orthogonal array is used for medium duty lathe for machining of Al6061T6.
  - Higher cutting speed and depth of cut leads to excellent surface finish, low feed rate leads to excellent surface finish, and variation in surface roughness is negligible with variation in nose radius.
  - The ANOVA analysis indicates that feed rate contributes 66%, nose radius contributes 65%, cutting speed contributes 49%, depth of cut contributes 28%, the interaction of nose radius and feed rate contributes 51%, the interaction of nose radius and cutting speed contributes 51% and the interaction of nose radius and depth of cut contributes 0% on surface roughness.

- L8 orthogonal array is used for medium duty lathe for machining of Al7075.
  - Higher cutting speed and depth of cut leads to excellent surface finish, low feed rate leads to excellent surface finish, and variation in surface roughness is negligible with variation in nose radius.
  - The ANOVA analysis indicates that feed rate contributes 81%, nose radius contributes 68%, cutting speed contributes 66% and depth of cut contributes 5%, the interaction of feed rate and speed contributes 42%, the interaction of
feed rate and depth of cut contributes 53% and the interaction of feed rate and nose radius contributes 0% on surface roughness.

- L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6.
  - Low feed rate and cutting speed leads to excellent surface finish, high depth of cut and rake angle at 10° gives excellent surface finish.
  - The ANOVA analysis indicates that cutting speed contributes 64.7%, depth of cut contributes 17.9%, feed rate contributes 9.4%, and rake angle contributes 8%.

- L31 orthogonal array is used for MTAB XLTURNS lathe for machining of Al7075.
  - The feed rate at 0.099 mm/rev gives excellent surface finish, high cutting speed and depth of cut leads to excellent surface finish, low rake angle gives excellent surface finish.
  - The ANOVA analysis indicates that cutting speed contributes 48.4%, rake angle contributes 19.6%, feed rate contributes 18.6% and depth of cut contributes 13.3%.

- Mathematical models relating surface roughness with cutting parameters like feed rate, cutting speed, depth of cut and nose radius are developed and found valid within the scope of the investigation.

The effects of cutting parameters on material removal rate were carried out for all standardised operational variables as per Taguchi technique.

- L8 orthogonal array is used for medium duty lathe for machining of Al6061T6.
  - Higher feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
The ANOVA analysis indicates that feed rate contributes 57%, depth of cut contributes 36%, nose radius contributes 49%, cutting speed contributes 28%, the interaction of nose radius and feed rate contributes 41%, the interaction of nose radius and cutting speed contributes 30% and the interaction of nose radius and depth of cut contributes 0% on material removal rate.

- L8 orthogonal array is used for medium duty lathe for machining of Al7075.
  - Higher feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
  - The ANOVA analysis indicates that cutting speed contributes 34%, feed rate contributes 27%, nose radius contributes 20% and depth of cut contributes 10%, the interaction of feed rate and speed contributes 18%, the interaction of feed rate and depth of cut contributes 32% and the interaction of feed rate and nose radius contributes 0% on material removal rate.

- L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6.
  - High feed rate, cutting speed and depth of cut leads to excellent surface finish, variation in material removal rate is negligible with variation in rake angle.
  - The ANOVA analysis indicates that depth of cut contributes 41.9%, cutting speed contributes 32.7%, feed rate contributes 24.5%, rake angle contributes 0.8%.

- L31 orthogonal array is used for MTAB XLTUR lathe for machining of Al7075.
  - High feed rate, cutting speed and depth of cut leads to excellent surface finish, variation in material removal rate is negligible with variation in rake angle.
  - The ANOVA analysis indicates that depth of cut contributes 38.1%, cutting speed contributes 37.1%, feed rate contributes 24.4% and rake angle contributes 0.4%.
Mathematical models relating surface roughness with cutting parameters like feed rate, cutting speed, depth of cut and nose radius are developed and found valid within the scope of the investigation.

The effects of cutting parameters on machining time were carried out for all standardised operational variables as per Taguchi technique.

- L8 orthogonal array is used for medium duty lathe for machining of Al6061T6.
  - Higher feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
  - The ANOVA analysis indicates that feed rate contributes 57%, depth of cut contributes 36%, nose radius contributes 49%, cutting speed contributes 28%, the interaction of nose radius and feed rate contributes 41%, the interaction of nose radius and cutting speed contributes 30% and the interaction of nose radius and depth of cut contributes 0% on machining time.
- L8 orthogonal array is used for medium duty lathe for machining of Al7075.
  - Higher feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
  - The ANOVA analysis indicates that feed rate contributes 100%, cutting speed contributes 100%, nose radius contributes 99%, depth of cut contributes 13%, the interaction of nose radius and feed rate contributes 48%, the interaction of feed rate and speed contributes 74%, the interaction of feed rate and depth of cut contributes 47% and the interaction of feed rate and nose radius contributes 0% on machining time.
- L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6.
High feed rate, cutting speed and depth of cut leads to excellent surface finish, variation in material removal rate is negligible with variation in rake angle.

The ANOVA analysis indicates that depth of cut contributes 75.9%, cutting speed contributes 21.2%, rake angle contributes 1.7% and feed rate contributes 1.1%.

L31 orthogonal array is used for MTAB XLTURN lathe for machining of Al7075.

The ANOVA analysis indicates that cutting speed contributes 63.8%, depth of cut contributes 34.5%, feed rate contributes 0.8% and rake angle contributes 0.8%.

Mathematical models relating material removal rate with cutting parameters like feed rate, cutting speed, depth of cut and nose radius are developed and found valid within the scope of the investigation.

The effects of cutting parameters on machining force were carried out for all standardised operational variables as per Taguchi technique.

L8 orthogonal array is used for medium duty lathe for machining of Al6061T6.

Low feed rate and depth of cut leads to excellent machining performance, whereas there is no variation in machining force with variation in cutting speed and nose radius.

The ANOVA analysis indicates that feed rate contributes 57.36%, depth of cut contributes 44.23%, nose radius contributes 0%, cutting speed contributes 0%, the interaction of nose radius and feed rate contributes 41.27%, the interaction
of nose radius and cutting speed contributes 0% and the interaction of nose radius and depth of cut contributes 0% on machining force.

- L8 orthogonal array is used for medium duty lathe for machining of Al7075.
  - Low feed rate and depth of cut leads to excellent machining performance, whereas there is no variation in machining force with variation in cutting speed and nose radius.
  - The ANOVA analysis indicates that feed rate contributes 50%, cutting speed contributes 34%, depth of cut contributes 0%, nose radius contributes 0%, the interaction of feed rate and speed contributes 18%, feed rate and depth of cut contributes 0% and feed rate and nose radius contributes 0% on machining force.

- L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6.
  - Low feed rate and depth of cut leads to excellent machining performance, whereas there is no variation in machining force with variation in cutting speed and rake angle.
  - The ANOVA analysis indicates that depth of cut contributes 51%, feed rate contributes 35.9%, cutting speed contributes 12.9% and rake angle contributes 0.2%.

- L31 orthogonal array is used for MTAB XLTURN lathe for machining of Al7075.
  - Low feed rate and depth of cut leads to excellent machining performance, whereas there is no variation in machining force with variation in cutting speed and rake angle.
  - The ANOVA analysis indicates that depth of cut contributes 61.1%, feed rate contributes 38.2%, cutting speed contributes 0.4% and rake angle contributes 0.4%.
Mathematical models relating machining force with cutting parameters like feed rate, cutting speed, depth of cut and nose radius are developed and found valid within the scope of the investigation.

The effects of cutting parameters on machining power were carried out for all standardised operational variables as per Taguchi technique.

- L8 orthogonal array is used for medium duty lathe for machining of Al6061T6.
  - Low feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
  - The ANOVA analysis indicates that feed rate contributes 57.36%, depth of cut contributes 35.86%, nose radius contributes 25.15%, cutting speed contributes 23.05%, the interaction of nose radius and feed rate contributes 41.27%, the interaction of nose radius and cutting speed contributes 29.53% and the interaction of nose radius and depth of cut contributes 0% on machining power.

- L8 orthogonal array is used for medium duty lathe for machining of Al7075.
  - Low feed rate, cutting speed, depth of cut and nose radius leads to excellent machining performance.
  - The ANOVA analysis indicates that cutting speed contributes 34%, feed rate contributes 27%, nose radius contributes 20% and depth of cut contributes 10%, the interaction of feed rate and speed contributes 18%, feed rate and depth of cut contributes 32% and feed rate and nose radius contributes 0% on machining power.

- L31 orthogonal array is used for CNC LT16 XI lathe for machining of Al6061T6.
o Low feed rate, cutting speed and depth of cut leads to excellent machining performance, whereas variation in machining power with variation in rake angle is negligible.

- The ANOVA analysis indicates that depth of cut contributes 39.7%, cutting speed contributes 34%, feed rate contributes 25.5% and rake angle contributes 0.8%.

- L31 orthogonal array is used for MTAB XLTURN lathe for machining of Al7075.

  o Low feed rate, cutting speed and depth of cut leads to excellent machining performance, whereas variation in machining power with variation in rake angle is negligible.

  o The ANOVA analysis indicates that feed rate contributes 38.1%, cutting speed contributes 37.1%, depth of cut contributes 24.4% and rake angle contributes 0.4%.

- Mathematical models relating machining power with cutting parameters like feed rate, cutting speed, depth of cut and nose radius are developed and found valid within the scope of the investigation.

It is hoped that the results of this systematic investigation is useful for industrial application especially for machining aluminium alloys AL6061T6 and Al7075.