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Study on Assessment and Prediction of Specific energy in rock cutting with Artificial Neural Network (ANN)

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ABSTRACT

In this rock cutting research, the bits used are point attack bits of 45°, 50°, 55° and 65° angles for each bits, the experiment is conducted on 45°, 55° and 65° attack angles. Keeping the RPM constant, varying the cutting force and torque during cutting, the depth of cut was measured and the cut material is collected and weighed. The objective is to estimate the specific energy during cutting process and to study the influence of attack angle on specific energy. From the experimental data, comparison of the results obtained were compared with [Artificial Neural Network (ANN)] to predict the cutting force and specific energy for the measured depth of cut and the results reveal that, the combination of 65° bit angles with 55° attack angle has produced optimum depth of cut with less cutting force and specific energy is increased with increase in depth of cut.

Keywords: Rock cutting, Bits, Specific Energy, rock properties, ANN

1. INTRODUCTION

The one common feature to all mechanical methods of coal extraction, whether involving in a hand pick, a coal drill, or a cutting machine, is that each depends for its action on the penetration of a wedge of some shape or form into the coal and rock face. In case of a hand pick, it is a single wedge being repeatedly struck at the face, the force and position of the blow being left to the experience and judgment of the mine worker. The intelligence of the miner and his inherent physical flexibility provides him with additional variables in the use of the wedge. It is certain that no mining machine is as efficient as a man in terms of the coal produced per unit of work done. However, mining machines can concentrate vastly more power in the confines of a coal face than can be obtained from manpower. A machine can deploy a large number of high-powered, fast-moving wedges to attack the coal, cutting prodigiously, but doing so in a 'non-thinking' repetitive fashion unresponsive to the type of opportunity for ease of extraction that could so ably be recognized and exploited by a coal hewer [1].

The basics of coal breakage is to, force the cutting tool into the rock under the thrusting action of the cutting machine. When the stresses generated in the rock by the penetrating action of the tool, when it exceeds the tensile or the shear strength of the rock, failure will occur in the form of fragments. Cutting tools provide the energy which is required to break the rock from the machine. Therefore, the geometry, wear characteristics and the energy transfer mechanisms of the cutting tools is a significant effect on the efficiency of the coal cutting process [2].

Mechanical excavation by point attack bit is crucial for the productivity of the rock cutting. Accurate prediction of the cutting force and specific energy helps to improve cutting efficiency and estimating the cutter head torque and machine power for different rock types. Therefore, prediction of the cutting force and specific energy becomes salient, which is attracted many mining researchers and experts to work on these important parameters, [3-7]. Evans developed a cutting force model [8] with the assumption that frictionless penetration of a point-attack bit gave rise to radial compressive stress and hoop tensile stress in the rock. When tensile stress in the rock reaches more than its tensile strength, breakage occurs, inducing symmetric, V-shaped fragments in the end and also assumed that the normal contact pressure between the bit and the rock should distribute uniformly and circumferentially along an imaginary hole. The simplification of the complex cutting process brought about theoretical contributions practically applicable to the mining field, in which, the predicted force could be considered as a reference to select the suitable power of cutting machine. However, from some succeeding rock cutting tests, it is found that, the estimated force deviated considerably from the measurements values.

Selection of pick for a particular condition is of paramount importance and a wrong selection can drastically increase the cost of the cutting operation. Ä method for predicting the suitable pick and machine type, therefore, emerges to be very important. A technique developed by Fowell and Smith is proved to be most useful for a successful operation [9, 10].

Point attack picks are classified among the tangential picks and generally is the shape of the common pencil and hence are also known as 'Pencil Point Tools'. They consist of a conical tungsten carbide tip which is inserted symmetrically into a cylindrical body, hence the pick axis is in line with the conical tip. Point attack picks had previously found considerable use in coal cutting; however, today, they are no longer favouring in this fiel :. They are increasingly employed in medium and hard rock cutting and is become an inevitable tool on medium and heavy-duty road headers [11].

The Attack angle which is the angle between the tool axis and the tangent of the cutting path, is another parameter affecting the performance of point attack picks. This angle provides a good contact between the pick rock and failure to position the pick at its correct attack angle will significantly alter the effective tool geometry. The kinematic requirements are also taken into account and practically this is suggested to be °, 50since at this value the lowest cutting forces are generated with the picks of 75° cone angle [12]. When cutting hard rock, the cone angle is increased and, consequently, the rake angle emerges to be smaller. In order to offset the value of clearance angle, the angle of attack is to be larger, e.g. at 90° cone angle, the angle of attack should be at least 55°. It is also reported that at high rotational speed, this angle should not exceed 48° [13].

The efficiency of a given rock cutting process is measured by the parameter specific energy SE, which is defined as the amount of work done in excavating a unit volume of rock. Specific energy is the most widely used parameter to measure the efficiency of a rock cutting system within a given rock, with lower values indicating higher efficiencies.

[Specific energy (SE)], is an essential parameter in rock cutting using a particular breakage method. It can also be taken as an index of the mechanical efficiency of a rock working process, to indicate drill/cutter conditions and rock characteristics such as strength, hardness, abrasiveness and texture. However, it is highly dependent on the mode of rock breakage, and the size and type of the equipment used. There are many methods of determining specific energy but results are only comparable if the cutting or apparatus is the same. Specific energy is also been used in relation to different excavation methods as a mode of evaluating efficiency [9,14,15]. The concept of specific energy is proposed by Fowell [11] as a quick means of assessing rock drillability. Teale, 1965 [16] defined SE as the energy required to remove a unit volume of rock Fowell [11]. The concept of the Specific energy is been utilized for many decades to assist in assessing the efficiency of the cutting processes and excavating the rock masses. It is a parameter that can be determined in real time from the data regarding the performance of a rock cutting machine.

The present investigation is carried out to assess and to predict the specific energy in rock cutting for different bit angles and with different attack angle for each bit-rock combinations used and is an important factor in rock cutting. In this study, the trends in the specific energy of point attack bits on different types of rocks are obtained. This work aims to investigate at what attack angle and bit angle at which the cutting force and specific energy is minimum for different rocks.

2. MECHANICAL PROPERTIES OF ROCK TESTED

The coal and sandstone blocks were collected from Ramagundem Area I, The [SingreniCollori Coal Ltd.,(SCCL)], Telangana state, limestone and dolomite blocks were collected from Chaitanya Industries, JK cements, Mudhapur, Bagalkot, Karnataka and also from Andhra Pradesh. Core sample were prepared and tested in rock mechanics laboratory, department of mining engineering, NITK as per the [International Society of Rock Mechanics (ISRM)] standards. The Mechanical Properties test d are uniaxial compressive strength, Brazilian tensile strength, elasticity modulus and density of the Rock tested is illustrated Below in Table 1.

2.1. Density

Trimmed core samples are used in the determination of natural density. The specimen volume is calculated from an average of several caliper readings and the weight of specimen is determined using a sensitive balance. The density data of sample was obtained from measurement of volume and mass and volume of each sample and using the following formula. Density (gm/m^3) = mass of the sample/ volume of sample. Three reading were taken and the average of results of test is shown in Table 1.

2.2. Uniaxial Compressive strength

Uniaxial Compressive Strength Test were performed on core samples having a diameter of 54 mm and length to diameter ratio of 2.5. The stress rate is applied within the range of 0.5-1.0 MPa/s.Load was applied continuously until the failure occurred. The maximum load (in kN) at failure was recorded. The [Uniaxial Compressive Strength (UCS)] of the specimen was calculated by dividing the maximum load carried by the specimen during the test, by the original cross-sectional area. Three reading were taken and the average of results of compressive test is shown in Table 1.

2.3. Brazilian tensile strength

Brazilian tensile strength (BTS)] tests are conducted on core samples having a diameter of 54mm and a length-to diameter ratio of 1. The tensile load on the specimens is applied at a constant stress rate such that failure would occur within 5mm of displacement. The tensile load on the specimen was applied continuously at stress rate of 200 N/s until sample failed. The maximum load (in kN) at failure was recorded. The BTS of the specimen was calculated by dividing the maximum load applied to the specimen by the original cross-sectional area. Three reading were taken and the average of results of test is shown in Table1.

2.4. Young's modulus

Young's Modulus is measured at a stress level equal to 50% of the ultimate uniaxial compressive strength. Loads and axial or deformations were recorded at evenly spaced load intervals during the test. Ten readings were taken over the load range to define the axial stress-strain curves. Then, the Young's Modulus of the specimen was calculated by dividing the ratio of the axial stress change to axial strain produced by the stress change. Three reading were taken and the average of results of test is shown in Table 1.

Table1

Mechanical properties of rock tested in laboratory

Rock	Density gm/m^3	σ_c (MPa)	σ_t (MPa)	E (GPa)
Coal 1	1.41	14.2	1.4	2.65
Coal 2	1.48	23.4	2.4	2.68
Sand Stone 1	1.92	14.1	1.4	6.8

Sand Stone 2	1.94	18.3	1.8	7.2
Sand Stone 3	1.95	24.2	2.5	9
Lime Stone 1	1.99	46.8	4.4	9.8
Lime stone 2	2.2	58.6	5.6	12.3
Lime Stone 3	2.69	69.7	6.8	12.4
Lime Stone 4	2.7	70.3	7.1	15.1
Dolomite 1	2.5	44.4	4.2	29
Dolomite 2	2.5	71.2	7.2	30.2

3. DESCRIPTION OF ROCK CUTTING MACHINE

The rock cutting machine (Figure.3.1.shows the Rock Cutting Machine)has been fabricated to study the influence of cutting parameters like thrust, torque and rpm on the results of cutting process. Rock cutting machine consists of a firm base with two parts protruding: one of the part has a prime mover (motor) mounted on it. A basplate attached to the motor has guide ways, which helps in moving to and fro movement and sideways also. A Motor is in turn is attached to a shaft pulley by elt drive. The cutter head is attached to the shaft by a flange. Cutter head consists of a drum with 12 number of bits are mountedon it. The other part of rock cutting machine has firm sample holder, in turn connected to a hydraulic cylinder, which can provide sideways movement during cutting operation and a material collecting bin. The block holder can accommodate a block of 0.3X0.3X0.45 M in dimension. In laboratory rock cutting, the rpm and thrust are varied from 225 to 325 and 1.3 to 2.1 kN respectively. During cutting process the cutting force and torque are measured by cutting tool dynamometer which is calibrated in the rock mechanics laboratory. For each rpm and thrust combination, cutting was done for 60 seconds and cutting depth was measured using Vernier caliper. The rocks considered for laboratory experiments are eleven types of rocks namely coal (two types), sand Stone (three types), lime stone (four types) and dolomite (two types). For each rpm-thrust combination, rock fragments which are produced during cutting process are collected and weighed. In this laboratory experiments, the attack angles of 45°, 55° and 65° are considered and for each attack angle, four bit angles namely 45°, 50°, 55° and 65° are considered for all bit-rock combination and operational parameters i.e. rpm and thrust considered during present laboratory investigation and the values are tabulated in Table.2 to 4. In this investigation, the influence of wear on cutting rate and specific energy were considered with wear of 5 mm were fabricated and used for all bit-rock combination considered and experiments are carried out for all rpm and thrust combination used and tabulated below.

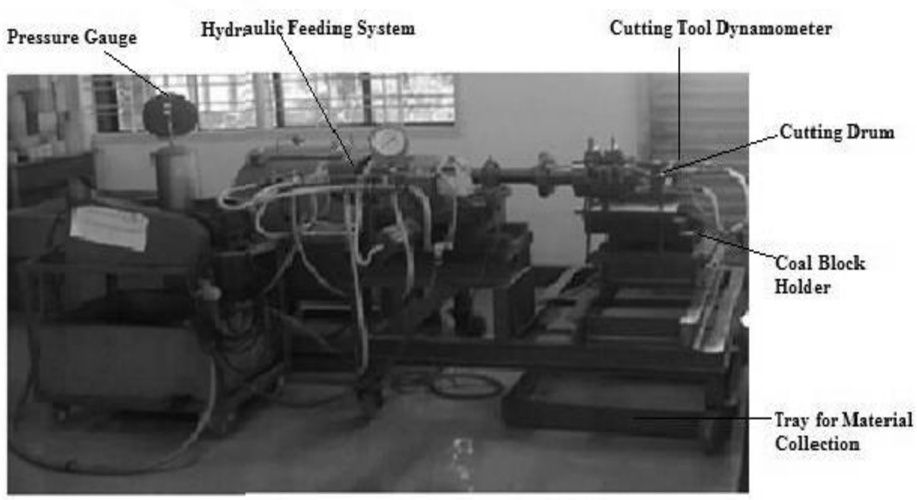

Figure 1
Rock cutting machine

Table 2

Experimental Result for45° Attack Angle with Different Tip Angles

Rock	Depth of cut (mm)	45° Bit angle		50° Bit angle		55° Bit angle		65° Bit angle	
		Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)
Coal 1	8.4	1.481	1.96	1.482	1.96	1.492	1.97	1.496	1.496
Coal 2	7.6	1.581	2.31	1.582	2.31	1.582	2.31	1.582	1.582
Sand Stone 1	7.6	1.581	2.31	1.586	2.32	1.592	2.33	1.586	1.586
Sand Stone 2	7.4	1.622	2.44	1.625	2.44	1.627	2.44	1.632	1.632
Sand Stone 3	7.3	1.634	2.49	1.635	2.49	1.636	2.49	1.638	1.638
Lime Stone 1	6.7	1.683	2.79	1.684	2.79	1.686	2.80	1.687	1.687
Lime stone 2	6.4	1.743	3.03	1.745	3.03	1.747	3.03	1.753	1.753
Lime Stone 3	6.3	1.754	3.09	1.756	3.10	1.757	3.10	1.758	1.758
Lime Stone 4	6.3	1.822	3.21	1.826	3.22	1.835	3.24	1.838	1.838
Dolomite 1	6.2	1.862	3.34	1.865	3.34	1.866	3.34	1.868	1.868
Dolomite 2	6.1	1.962	3.57	1.965	3.58	1.967	3.58	1.968	1.968

Table 3

Experimental Result for 55° Attack Angle with Different Tip Angles

Rock	Depth of cut (mm)	45°Bit an le		50°Bit angle		55°Bit angle		65°Bit angle	
		Cutting force (kN)	Specific nergy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energ (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)
Coal 1	11.3	1.381	1.50	1.385	1.50	1.387	1.36	1.392	1.37
Coal 2	7.6	1.481	1.58	1.482	1.58	1.483	2.17	1.484	2.17
Sand Stone 1	7.6	1.485	1.59	1.487	1.59	1.49	2.18	1.493	2.18
Sand Stone 2	7.4	1.525	1.63	1.53	1.63	1.534	2.30	1.535	2.30
Sand Stone 3	7.2	1.535	1.64	1.537	1.64	1.537	2.37	1.538	2.37
Lime Stone 1	6.7	1.583	1.69	1.585	1.69	1.585	2.63	1.586	2.63
Lime stone 2	6.4	1.65	1.75	1.653	1.75	1.654	2.87	1.655	2.87
Lime Stone 3	6.3	1.656	1.76	1.658	1.76	1.659	2.93	1.659	2.93
Lime Stone 4	6.3	1.725	1.84	1.727	1.84	1.731	3.05	1.734	3.06
Dolomite 1	6.2	1.765	1.87	1.765	1.87	1.767	3.17	1.767	3.17
Dolomite 2	6.1	1.865	1.97	1.865	1.97	1.867	3.40	1.867	3.40

Table 4

Experimental Result for 65° Attack Angle with Different Tip Angles

Rock	Depth of cut (mm)	45°Bit angle		50°Bit angle		55°Bit angle		65°Bit angle	
		Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)
Coal 1	4.9	1.661	3.77	1.665	3.78	1.665	3.78	1.666	3.78
Coal 2	6.5	1.681	2.87	1.683	2.88	1.684	2.88	1.69	2.89
Sand Stone 1	5.2	1.692	3.62	1.695	3.62	1.696	3.62	1.698	3.63

Sand Stone 2	5.1	1.712	3.73	1.713	3.73	1.714	3.73	1.715	3.74
Sand Stone 3	4.9	1.721	3.90	1.721	3.90	1.723	3.91	1.731	3.93
Lime Stone 1	4.9	1.735	3.93	1.735	3.93	1.736	3.94	1.737	3.94
Lime stone 2	4.9	1.745	3.96	1.746	3.96	1.749	3.97	1.752	3.97
Lime Stone 3	4.8	1.754	4.06	1.755	4.06	1.755	4.06	1.757	4.07
Lime Stone 4	4.7	1.882	4.45	1.89	4.47	1.894	4.48	1.895	4.48
Dolomite 1	4.6	1.896	4.58	1.897	4.58	1.897	4.58	1.899	4.59
Dolomite 2	4.7	2.065	4.88	2.065	4.88	2.068	4.89	2.078	4.91

Table 5

Experimental Result for 45° Tip Angle with 5mm wear for Different Attack Angle

Rock	Depth of cut (mm)	45°Attack angle		55°Attack angle		65°Attack angle	
		Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)	Cutting force (kN)	Specific energy (KJ/m^3)
Coal 1	6.8	1.725	2.82	1.725	2.82	1.727	2.82
Coal 2	6.6	1.76	2.96	1.761	2.96	1.764	2.97
Sand Stone 1	6.5	1.821	3.11	1.821	3.11	1.825	3.12
Sand Stone 2	6.4	1.835	3.19	1.841	3.20	1.841	3.20
Sand Stone 3	5.8	1.842	3.53	1.843	3.53	1.846	3.54
Lime Stone 1	5.3	1.871	3.92	1.875	3.93	1.875	3.93
Lime stone 2	5.2	1.876	4.01	1.877	4.01	1.877	4.01
Lime Stone 3	5.2	1.95	4.17	1.95	4.17	1.952	4.17
Lime Stone 4	5.2	1.952	4.17	1.954	4.18	1.954	4.18
Dolomite 1	5.1	1.956	4.26	1.958	4.27	1.958	4.27
Dolomite 2	4.9	2.045	4.64	2.045	4.64	2.048	4.64

4. RESULTS & DISCUSSIONS

4. 1. Artificial Neuron Network model

The Artificial neural networks technology has many useful properties and it is widely employed in mining and tunneling applications. The feed- forward back propagation network is chosen to build a predictive model for cutting force and specific energy in this study. The input layer has thirteen (like Density, UCS, BTS, Youngs modulus, Poisson's Ratio, RPM, Attack angle, bit angle, cutting force, depth of cut, torque, volume broken, cutting rate corresponding to the predictors in the model. The single hidden layer has tangent sigmoid transfer function neurons. While the output layer has one pure linear neuron corresponding to cutting force and specific energy. The number of hidden neurons is selected as 10. This network architecture is known as a useful neural network structure for function approximation or regression problems.

Before implementing ANN, the data set is divided up into training (70%), validation (15%), and test (15%) subsets. The sets are picked randomly throughout the data set. ANN is built, trained and implemented with MATLAB neural network toolbox using the Levenberg-Marquardt algorithm for back propagation.

Network errors for the neural network model of cutting force and specific energy are calculated to check the progress of training. The results shown in Figure 4.1 to 4.32 for the model are reasonable, since the test set errors and the validation set errors have similar characteristics, and no significant over fitting occurs. The network responses are also analyzed for the neural network model. After unmoral the network outputs, the entire data set is put through the network and linear regression is performed between the network outputs and the corresponding targets for cutting force and specific energy. The neural network model gives predicted cutting force and specific energy values very close to those measured and calculated as expressed by an R-value more than 97% for 55° attack angle.

4.2. Discussions

Assessment of the bit-rock interaction reveals a significant number of parameters affecting performance of cutting efficiency. These findings are summarized as follows

1. The magnitude of cutting and cutting forces is dependent on the area of contact between the bits and the rock. The smaller the bit, smaller is the area of contact between bit and rock like 45°, 50° and 55° bit angle, smaller bit angle increased cutting force and reduced depth of cut.
2. Larger bit tip imposed more damage to the rock by deeper cuts like 65° bit angle , results in more rupture and decreased specific energy during cutting, particularly in multi bit interaction, provided maximum depth of cut compared with other types of bit angles.
3. An optimum area of contact is ensured by 65° bit angle in order to have sufficient bit penetration and prolong life of the bit, that is to say small bit like 45°, 50° and 55° bit angle will not last too long, while a larger bit last longer with optimum penetration.
4. The Specific energy and cutting force has increased with increase in depth of cut of rock tested.
5. Depth of cut tends to decrease with increase in strength of rocks.

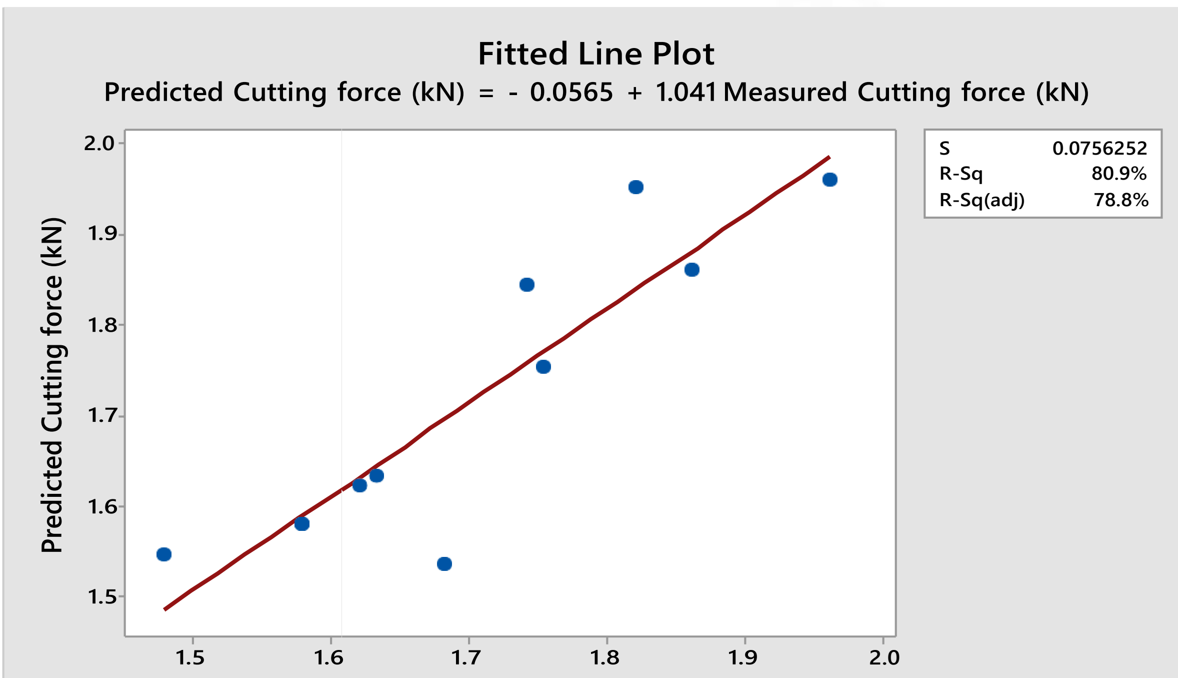

Figure 4.1

Scatter plot of Cutting force values predicted by ANN versus Measured values for 45° bit angle with45°Attack angle

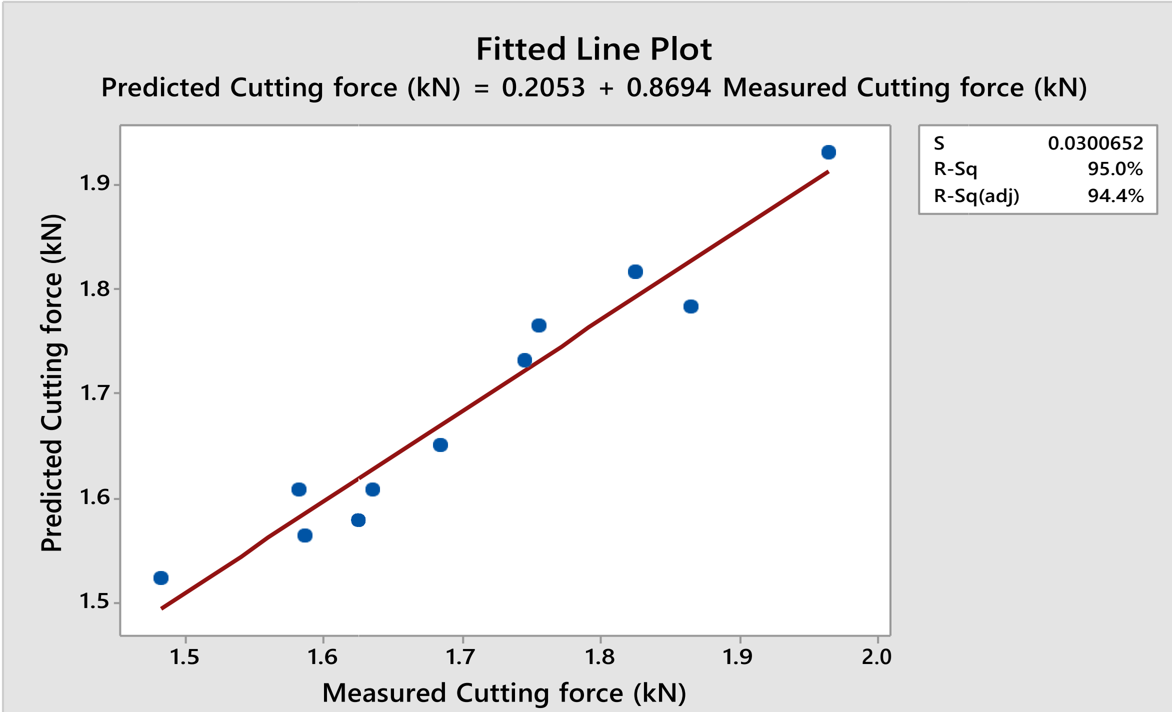

Figure 4.2
Scatter plot of Cutting force values predicted by ANN versus Measured values for 50° bit angle with 45°Attack angle

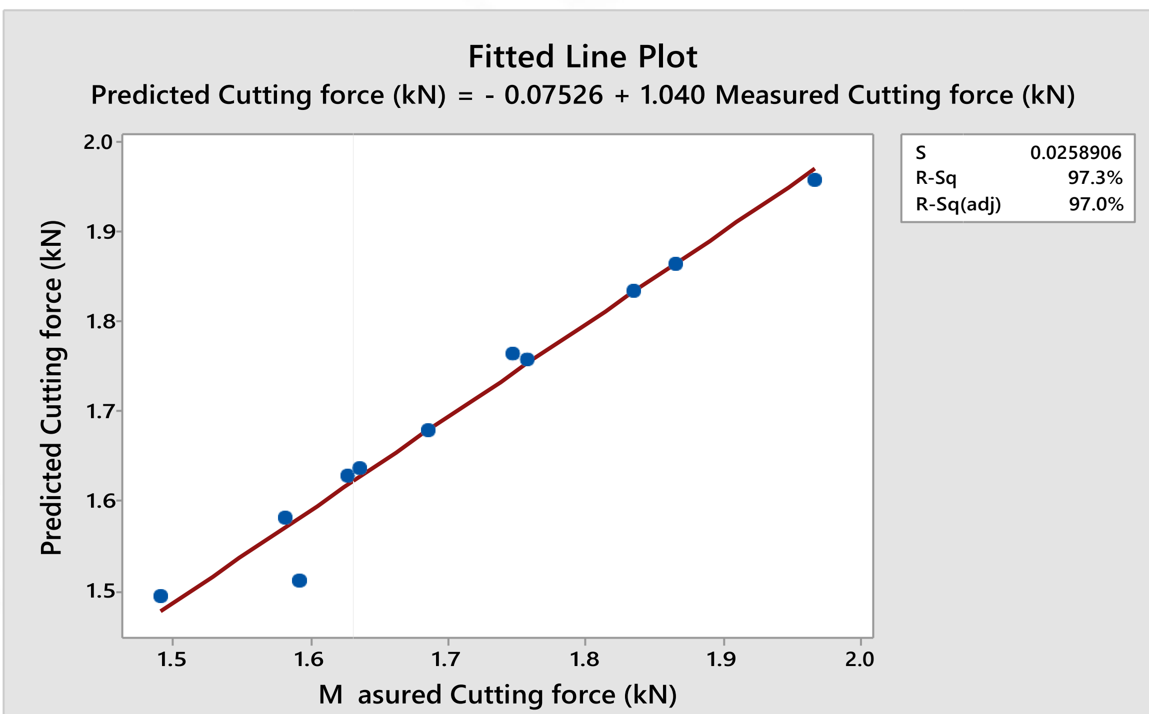

Figure 4.3
Scatter plot of Cutting force values predicted by ANN versus Measured values for 55° bit angle with 45°Attack angle

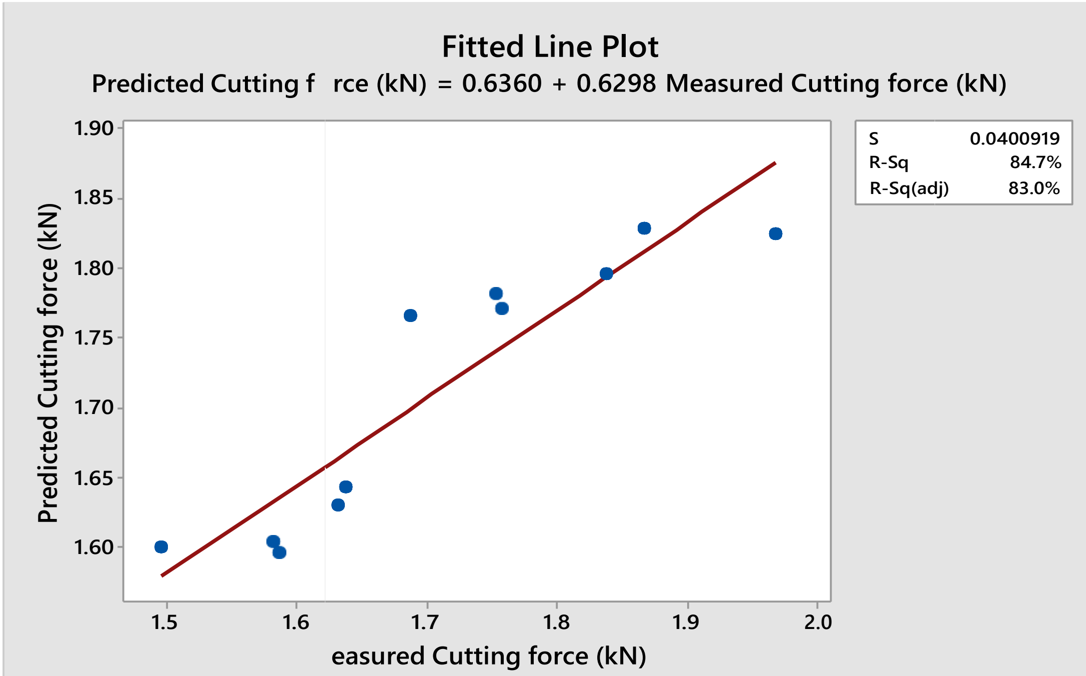

Figure 4.4

Scatter plot of Cutting force values predicted by ANN versus Measured values for 65° bit angle with 45°Attack angle

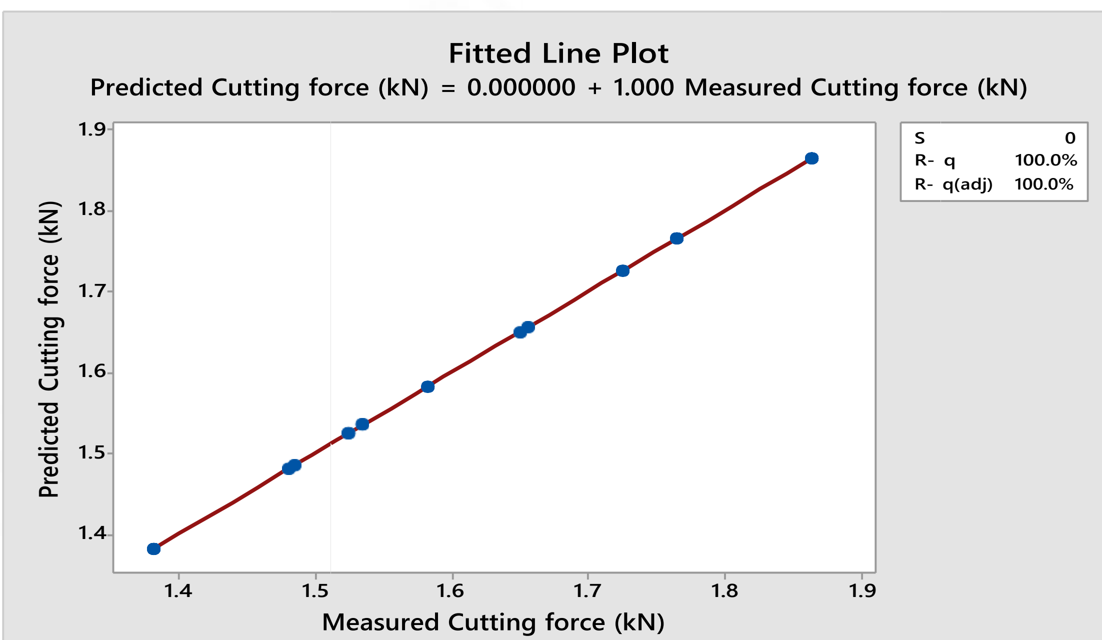

Figure 4.5

Scatter plot of Cutting force values predicted by ANN versus Measured values for 45° bit angle with 55°Attack angle

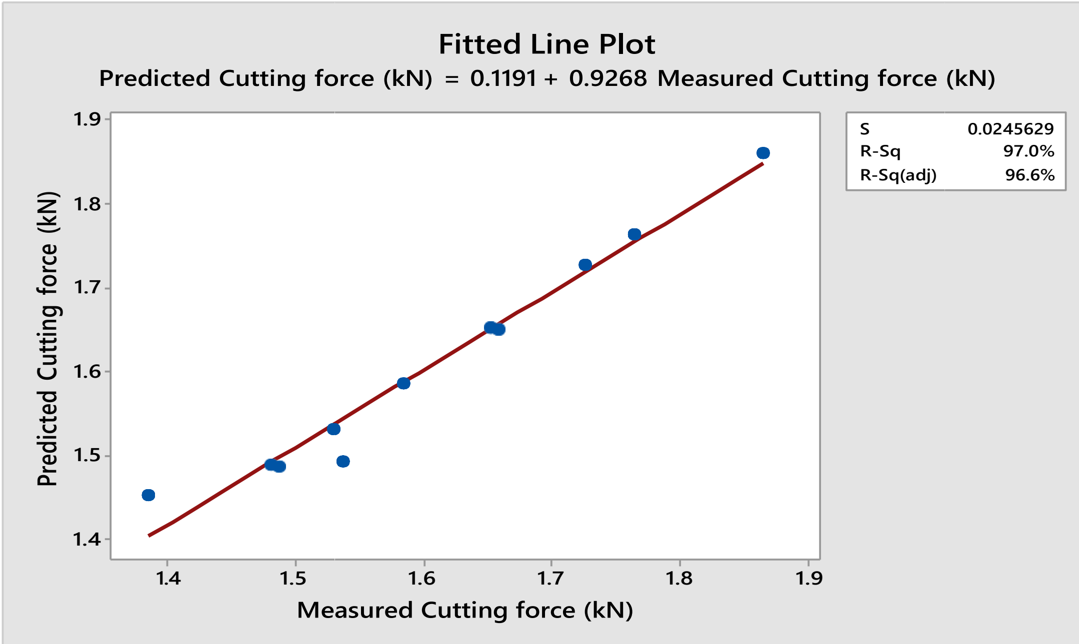

Figure 4.6

Scatter plot of Cutting force values predicted by ANN versus Measured values for 50° bit angle with 55°Attack angle

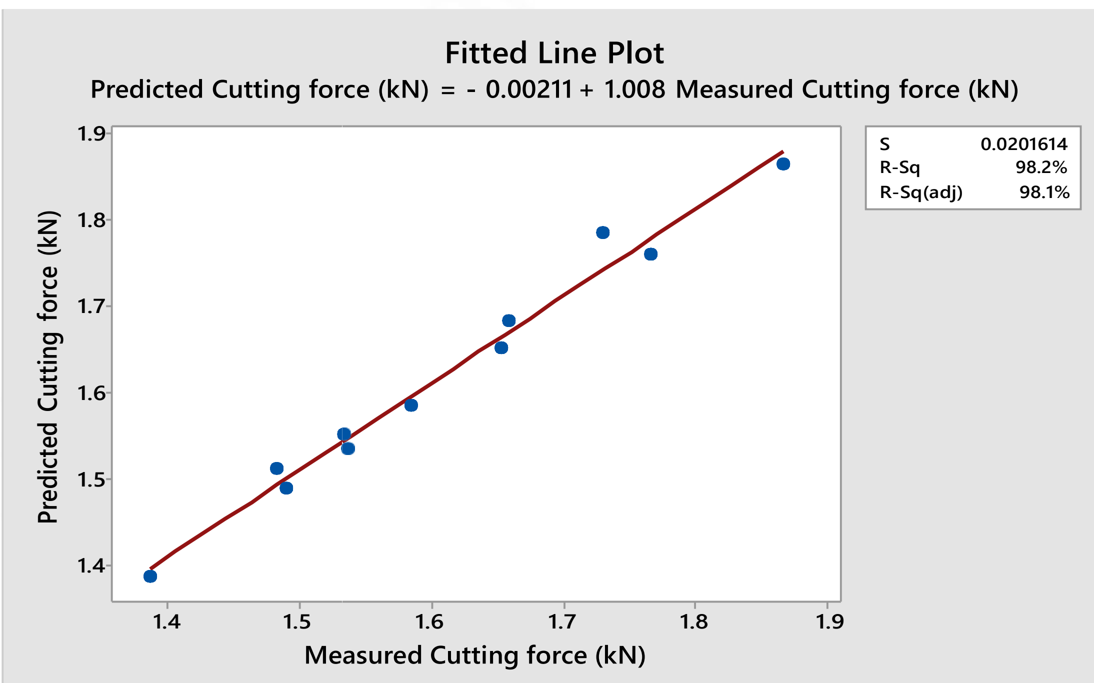

Figure 4.7

Scatter plot of Cutting force values predicted by ANN versus Measured values for 55° bit angle with 55°Attack angle

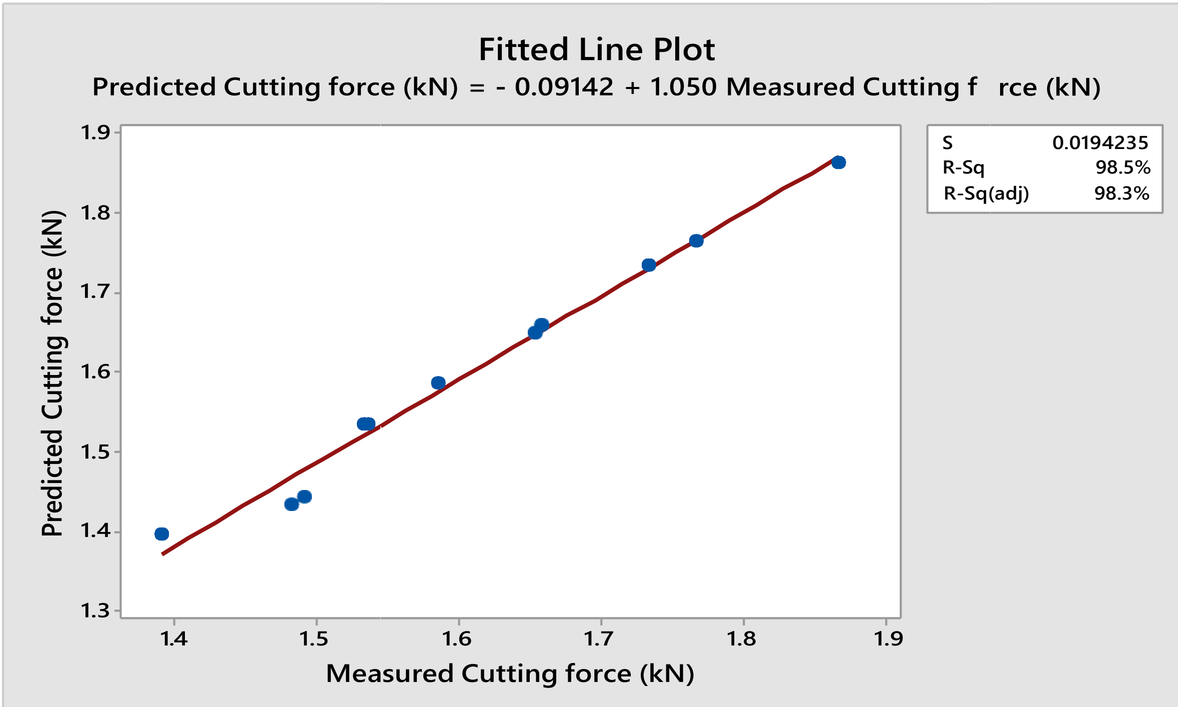

Figure 4.8

Scatter plot of Cutting force values predicted by ANN versus Measured values for 65° bit angle with 55°Attack angle

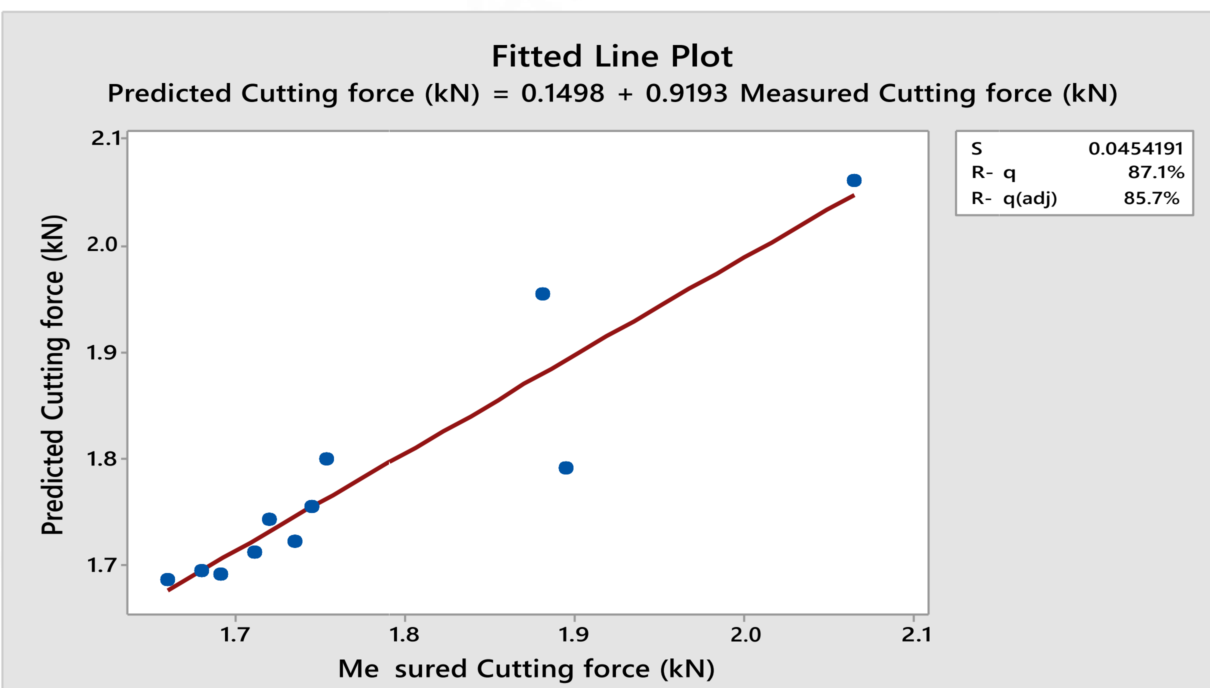

Figure 4.9

Scatter plot of Cutting force values predicted by ANN versus Measured values for 45° bit angle with 65° Attack angle

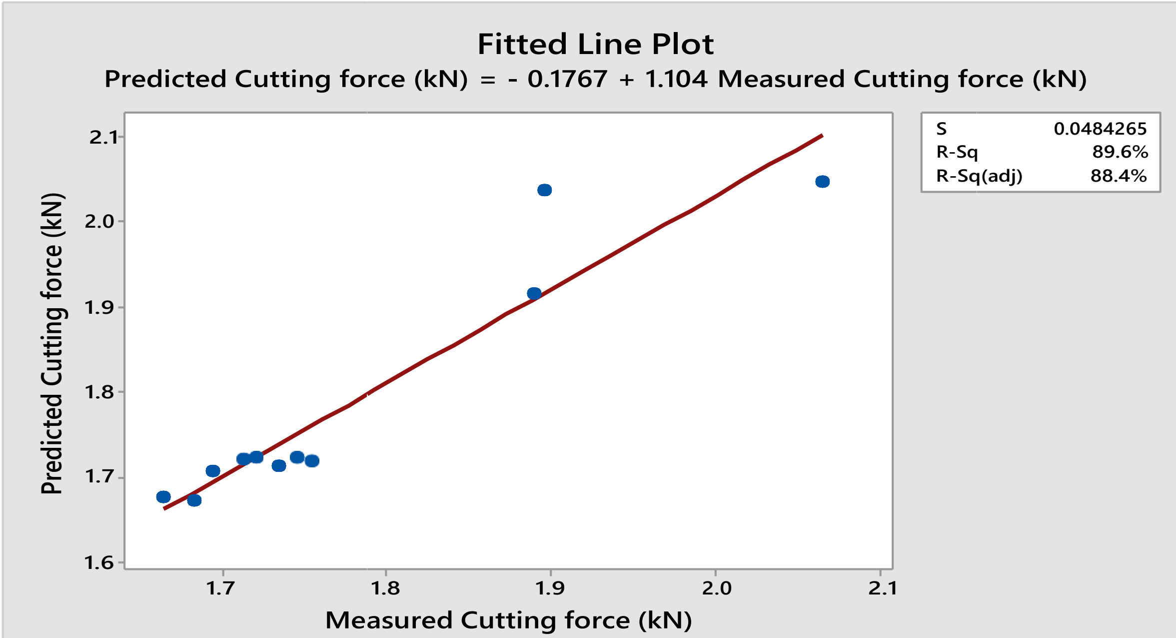

Figure 4.10

Scatter plot of Cutting force values predicted by ANN versus Measured values for 50° bit angle with 65°Attack angle

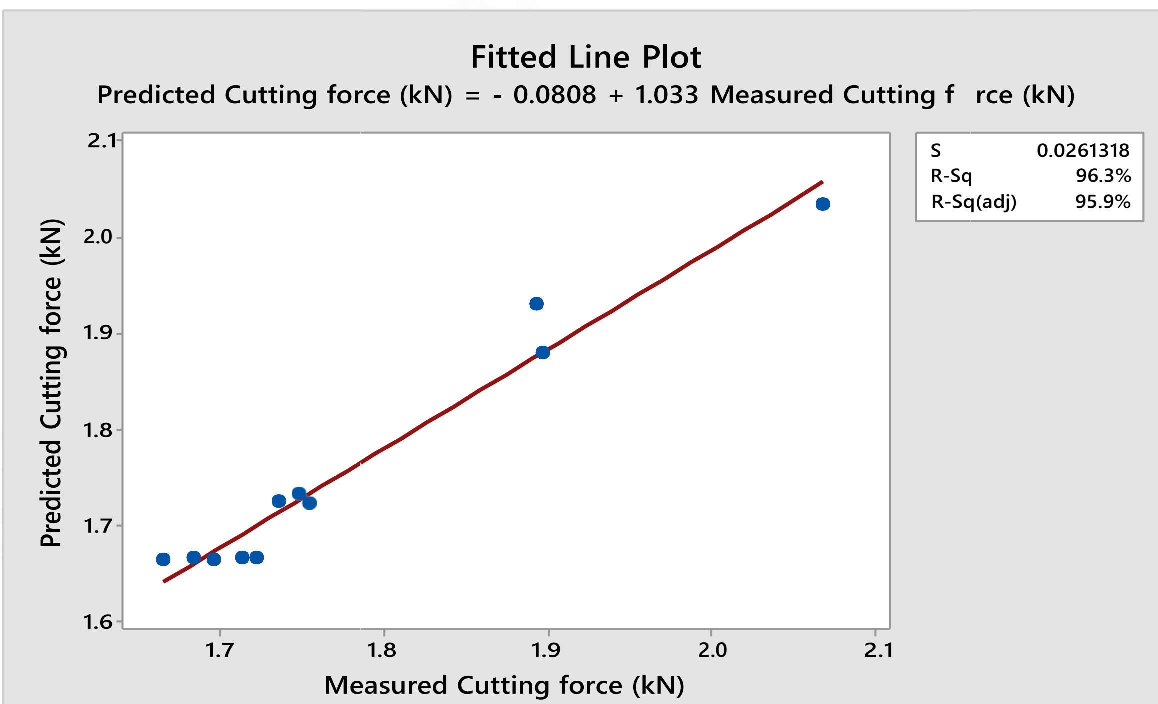

Figure 4.11

Scatter plot of Cutting force values predicted by NN versus Measured values for 55° bit angle with 65°Attack angle

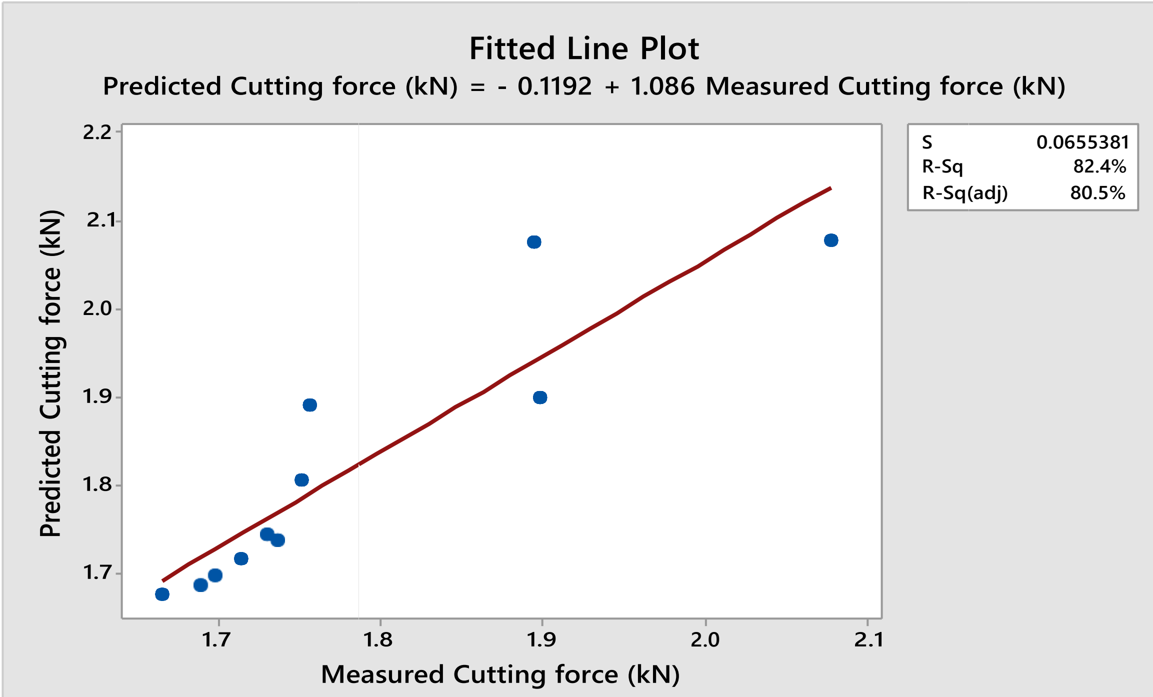

Figure 4.12

Scatter plot of Cutting force values predicted by ANN versus Measured values for 65° bit angle with 65°Attack angle

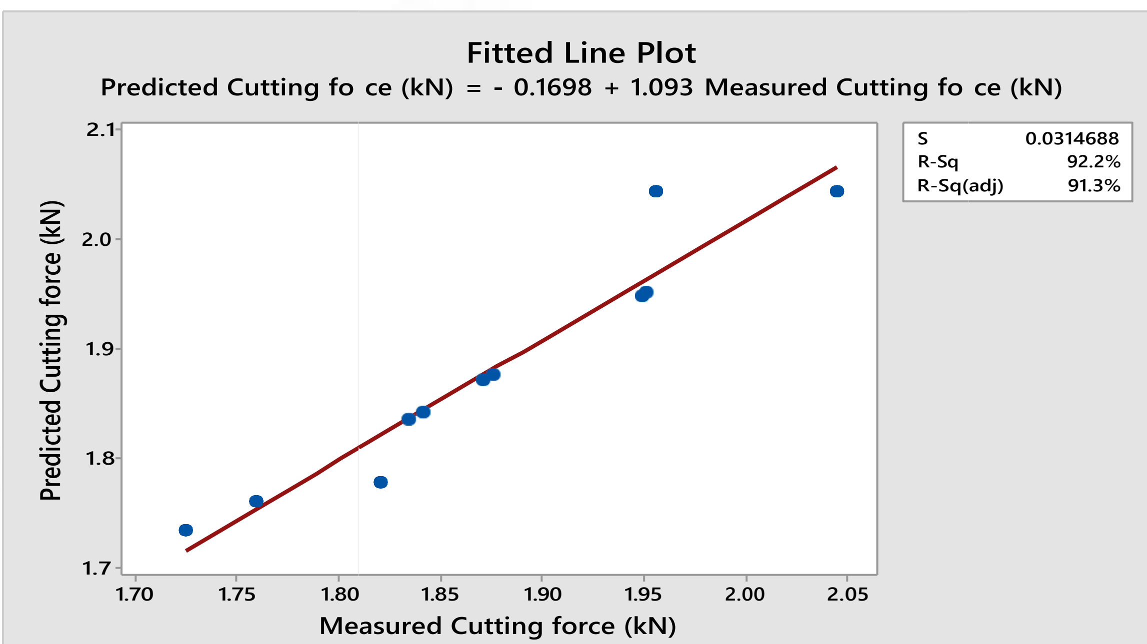

Figure 4.13

Scatter plot of Cutting force values predicted by ANN versus Measured values for 45° bit angle with 5mm wear for 45° Attack angle

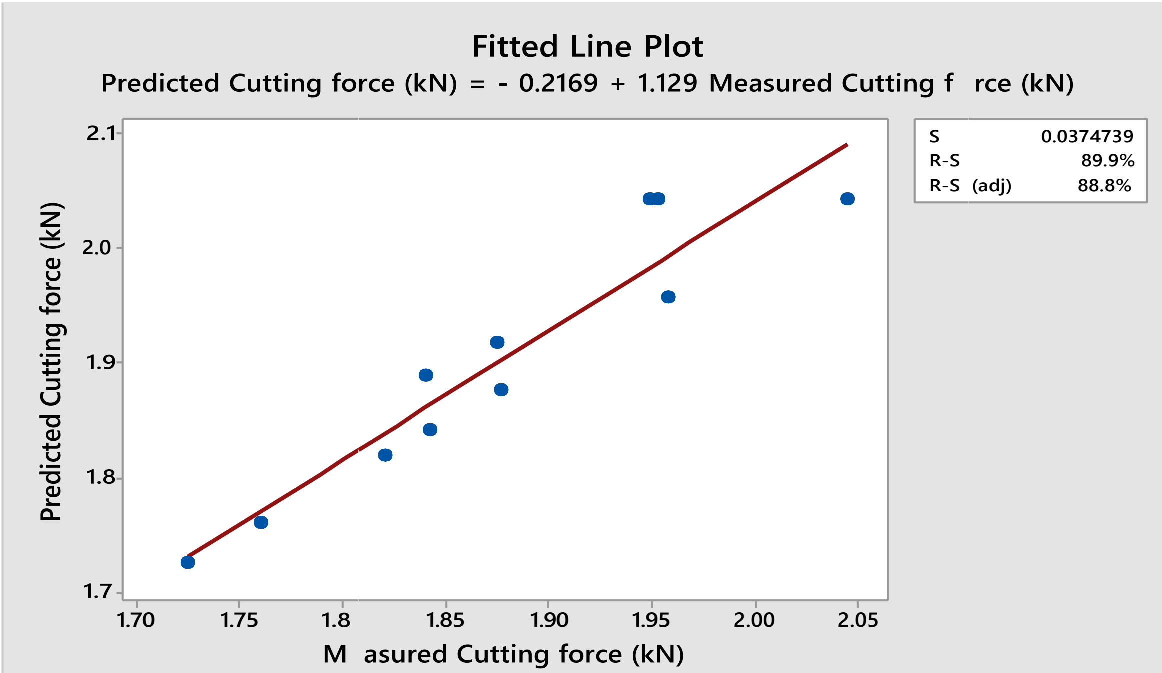

Figure 4.14

Scatter plot of Cutting force values predicted by ANN versus Measured values for 50° bit angle with 5mm wear for 45° Attack angle

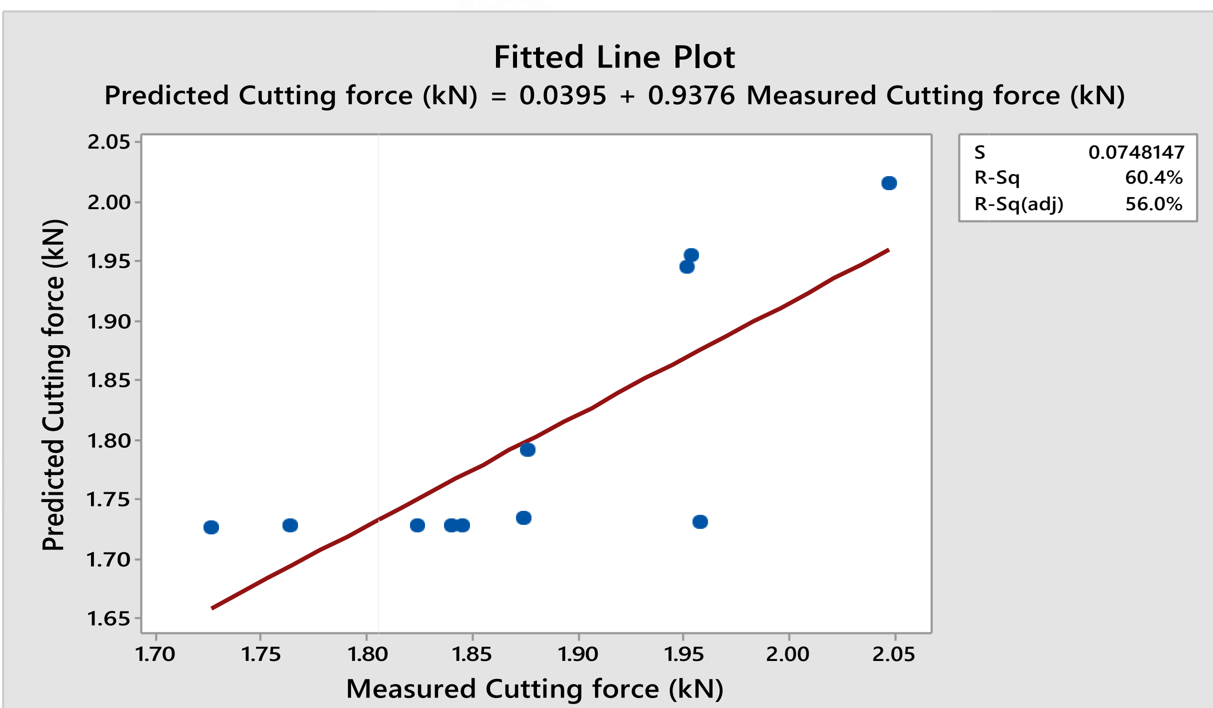

Figure 4.15

Scatter plot of Cutting force values predicted by ANN versus Measured values for 55° bit angle with 5mm wear for 65° Attack angle.

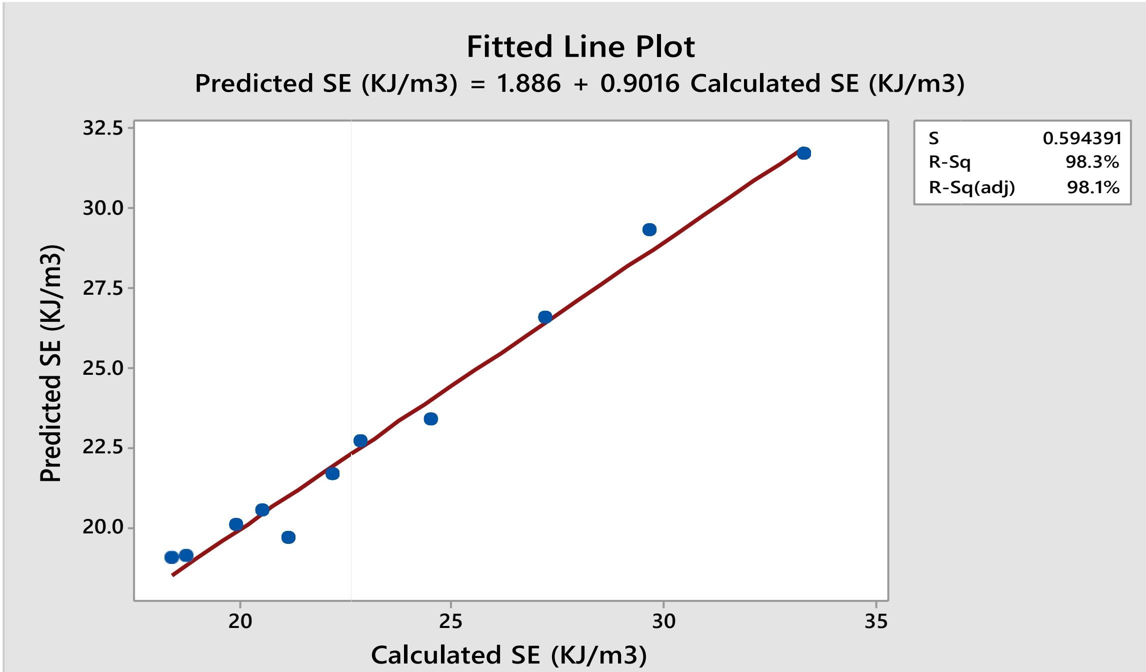

Figure 4.16

Scatter plot of Specific energy values predicted by ANN versus Measured values for 65° bit angle at 45°Attack angle

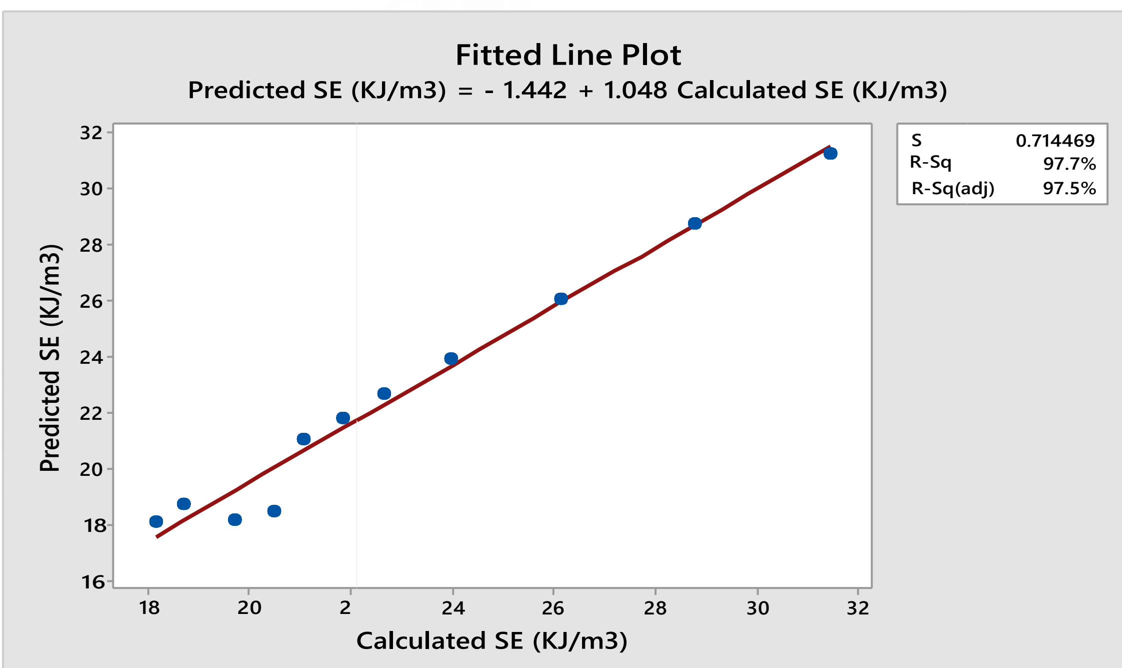

Figure 4.17

Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle at 45°Attack angle

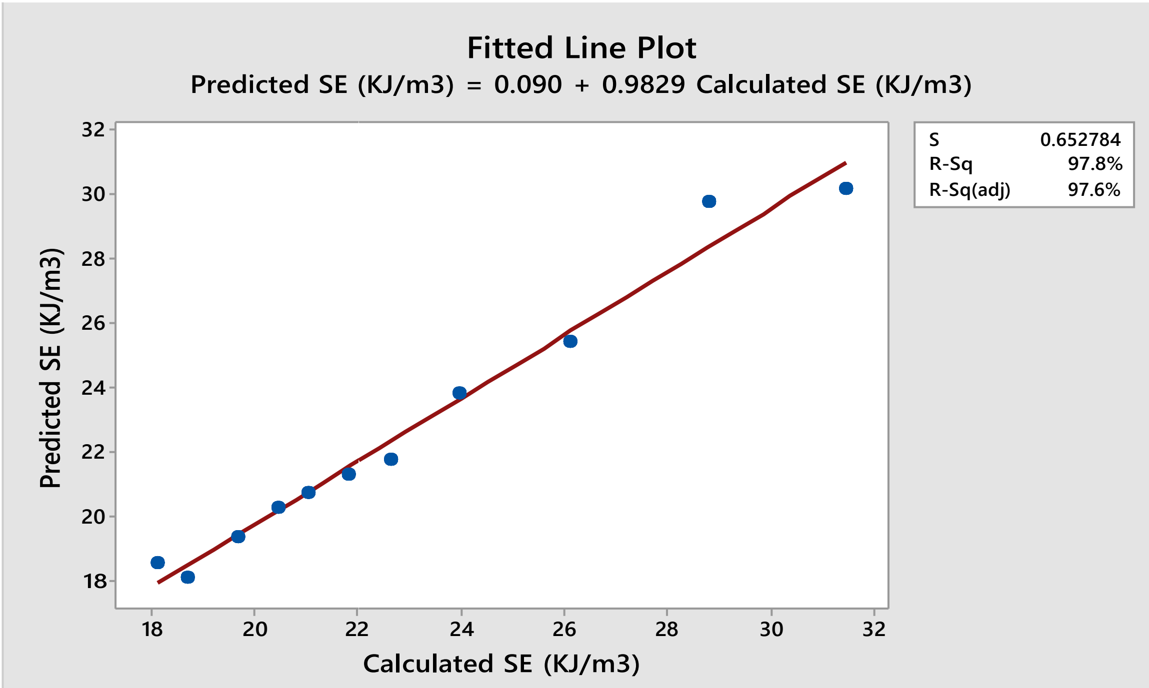

Figure 4.18

Scatter plot of Specific energy values predicted by ANN versus Measured values for 55° bit angle at 45°Attack angle

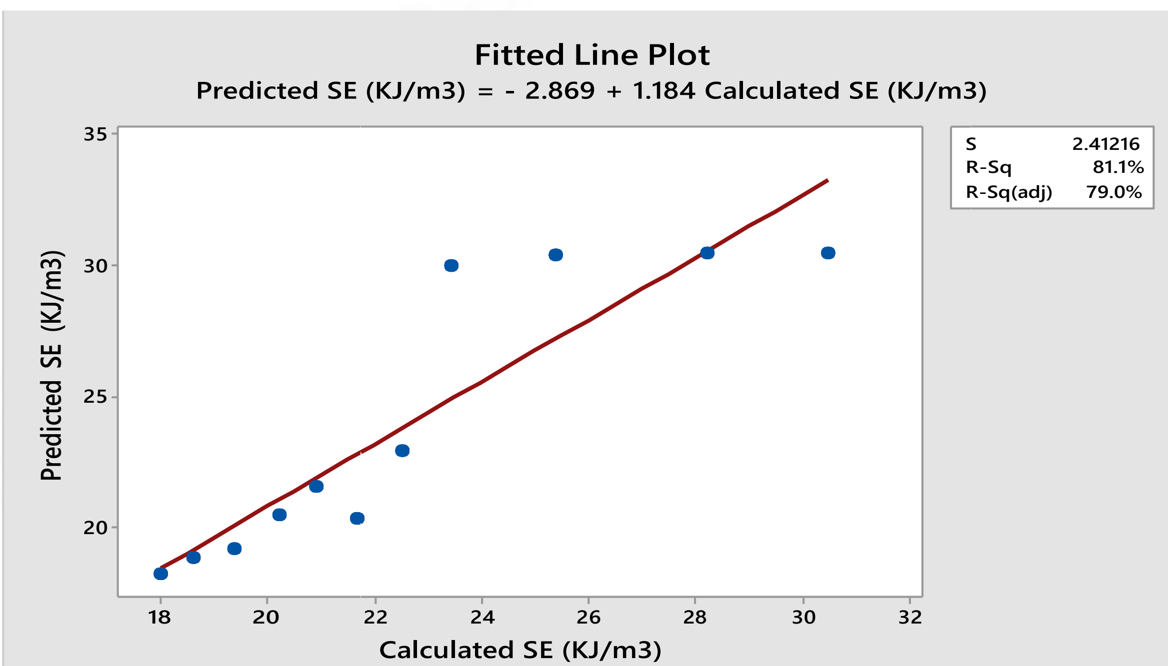

Figure 4.19

Scatter plot of Specific energy values predicted by ANN versus Measured values for 65° bit angle at 45°Attack angle

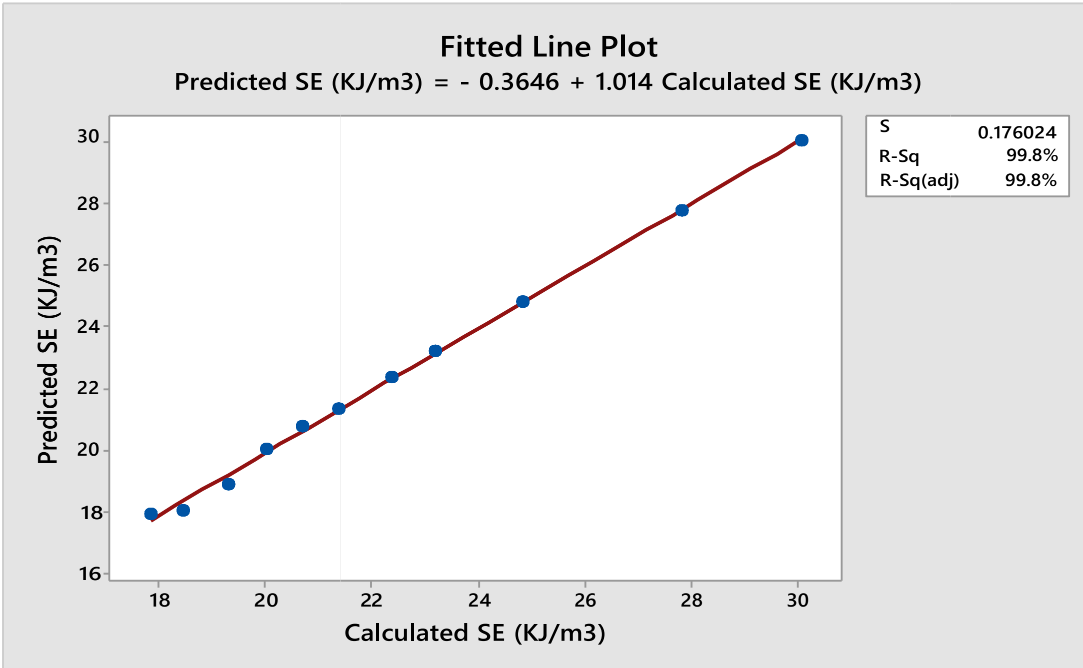

Figure 4.20

Scatter plot of Specific energy values predicted by ANN versus Measured values for 45° bit angle at 55°Attack angle

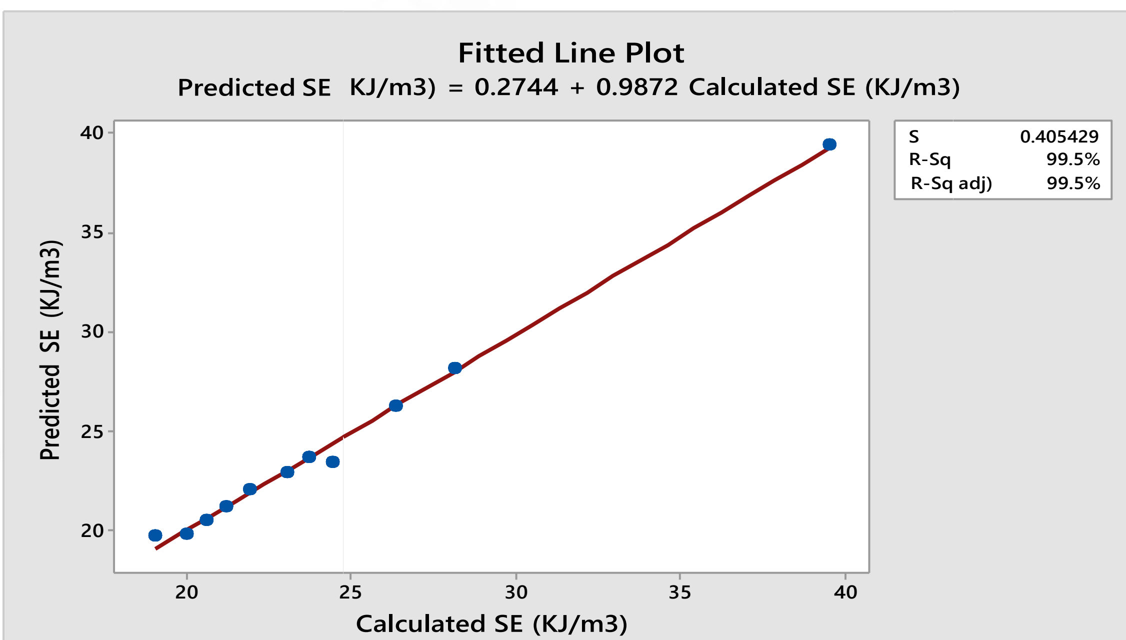

Figure 4.21

Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle at 55°Attack angle

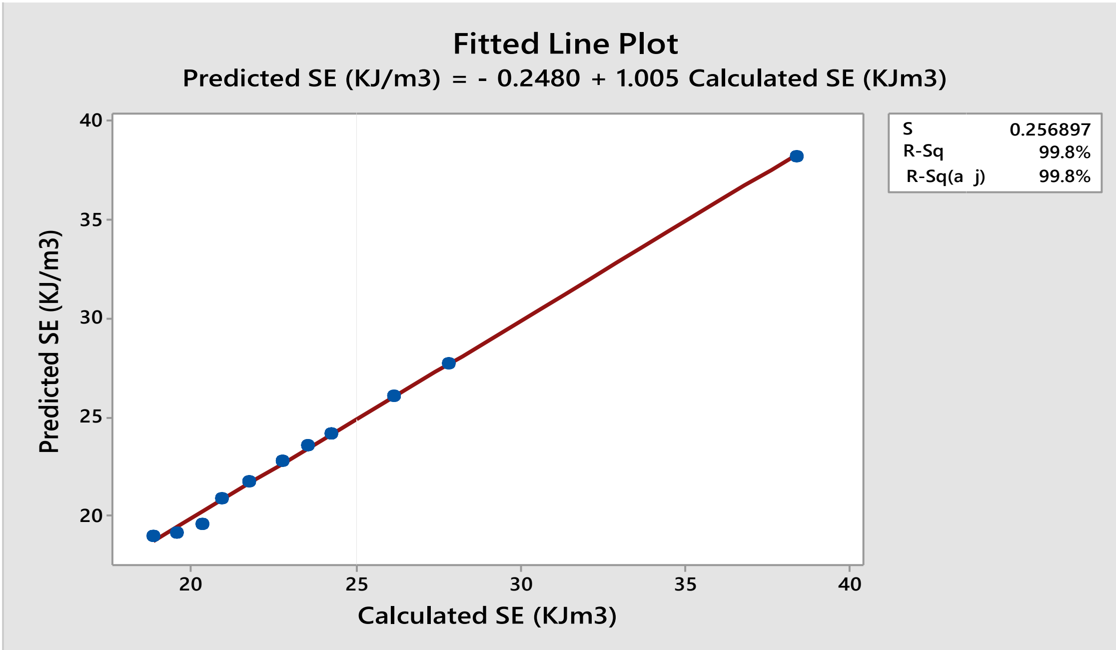

Figure 4.22
Scatter plot of Specific energy values predicted by ANN versus Measured values for 55° bit angle at 55°Attack angle

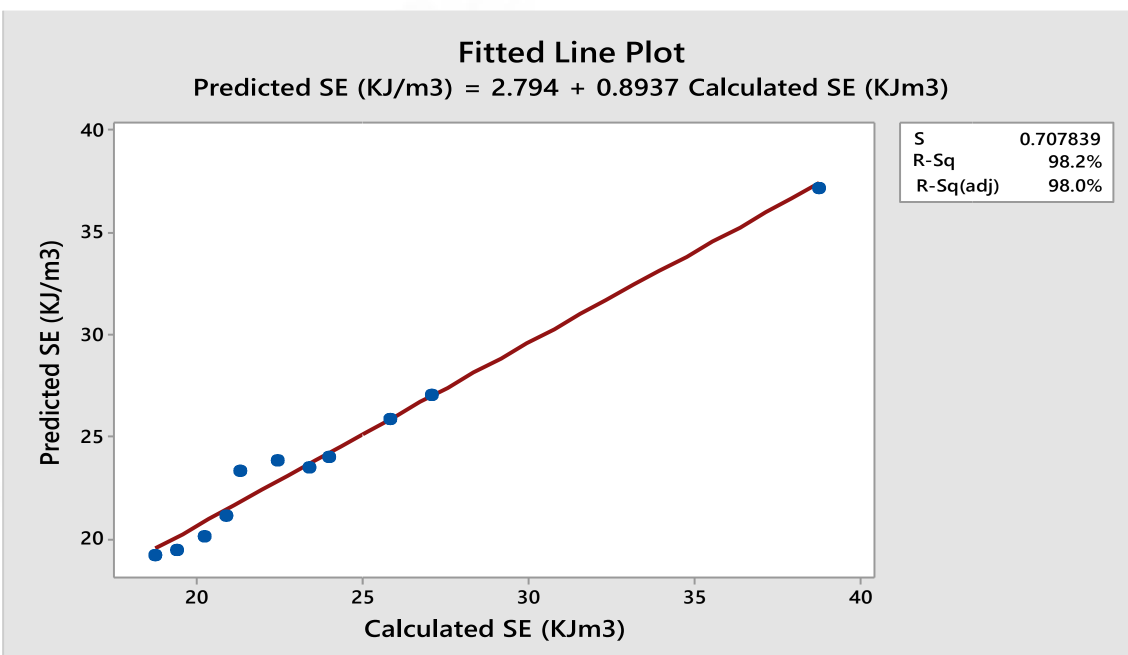

Figure 4.23
Scatter plot of Specific energy values predicted by ANN versus Measured values for 65° bit angle at 55°Attack angle

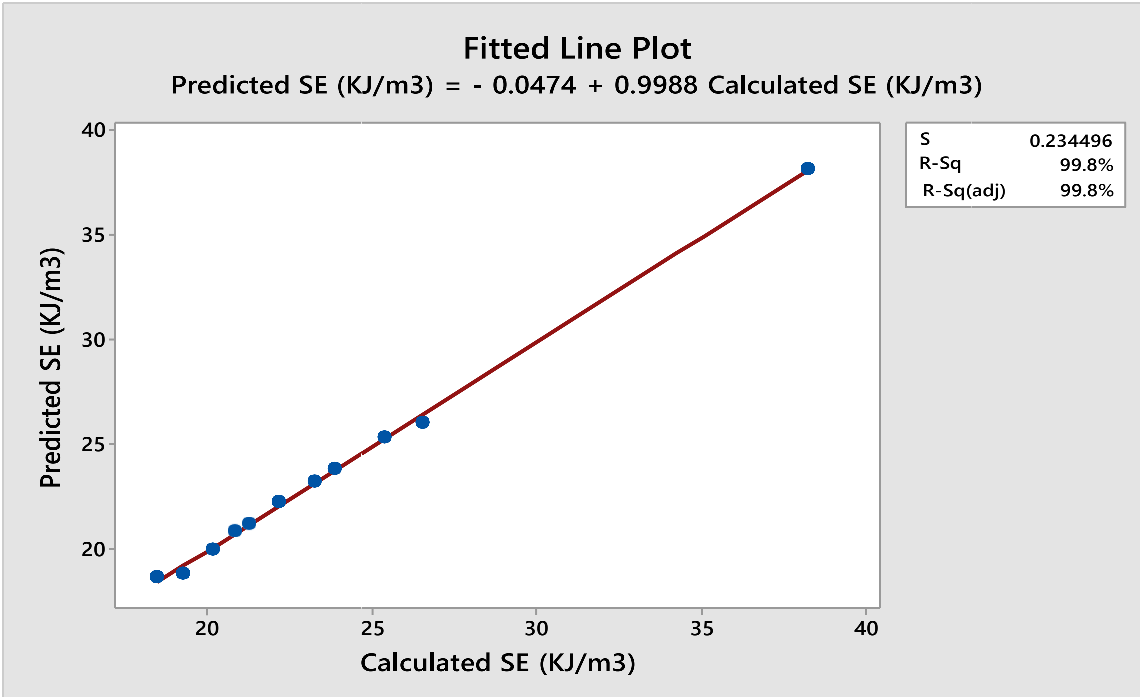

Figure 4.24

Scatter plot of Specific energy values predicted by ANN versus Measured values for 45° bit angle at 65°Attack angle

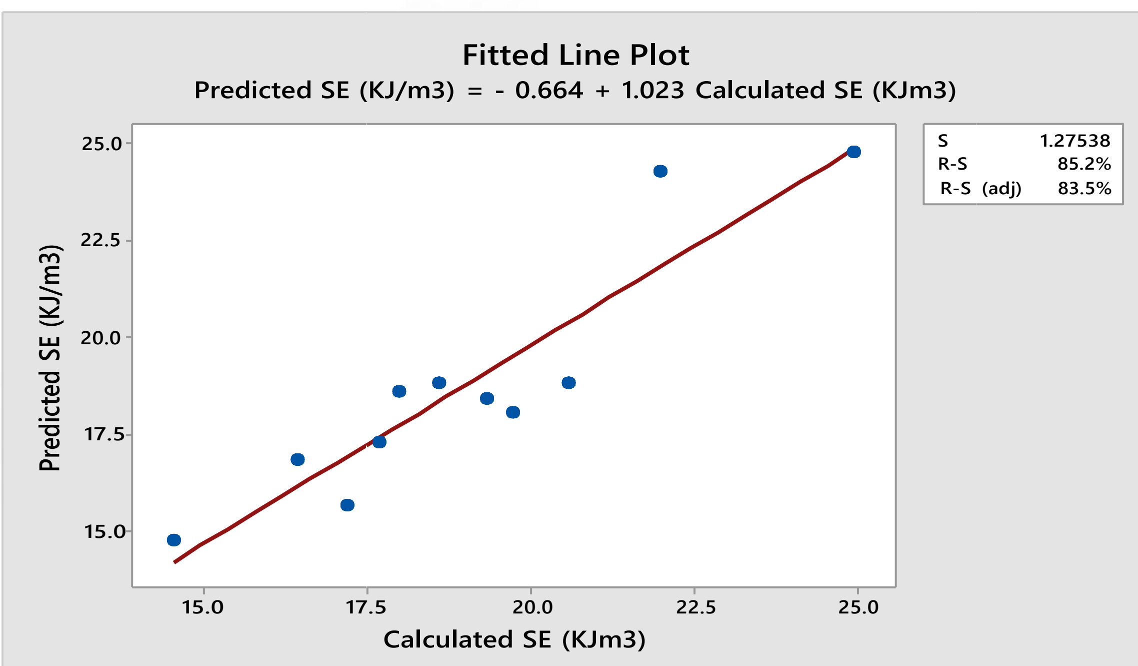

Figure 4.25

Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle at 65°Attack angle

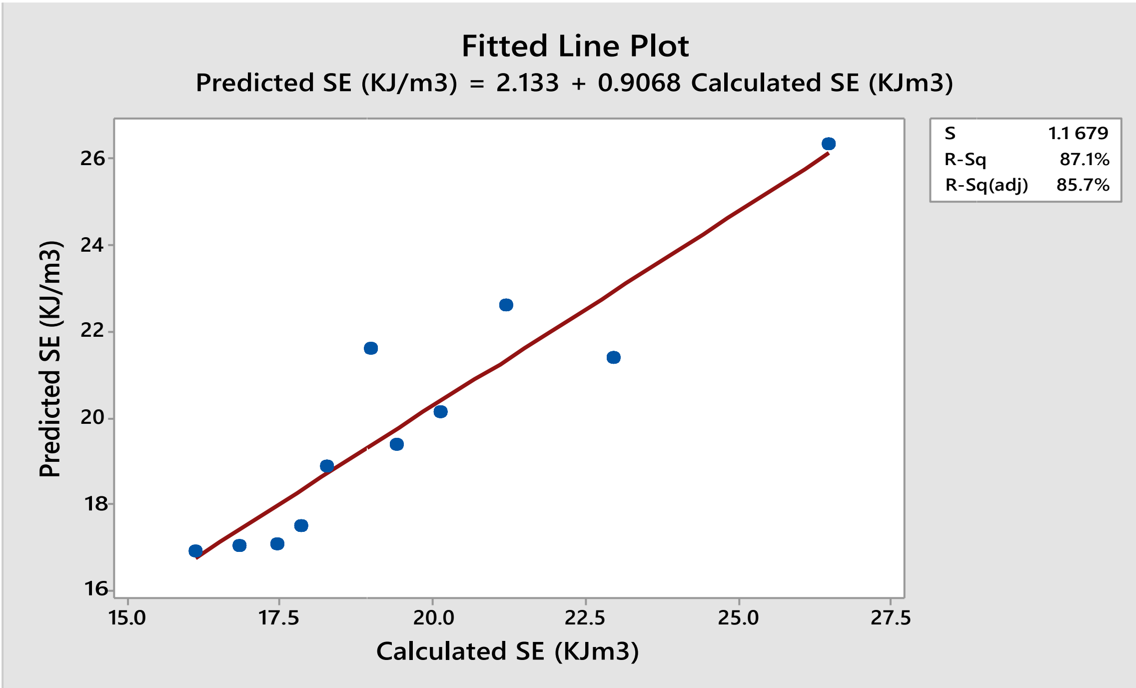

Figure 4.26
Scatter plot of Specific energy values predicted by ANN versus Measured values for 55° bit angle at 65°Attack angle

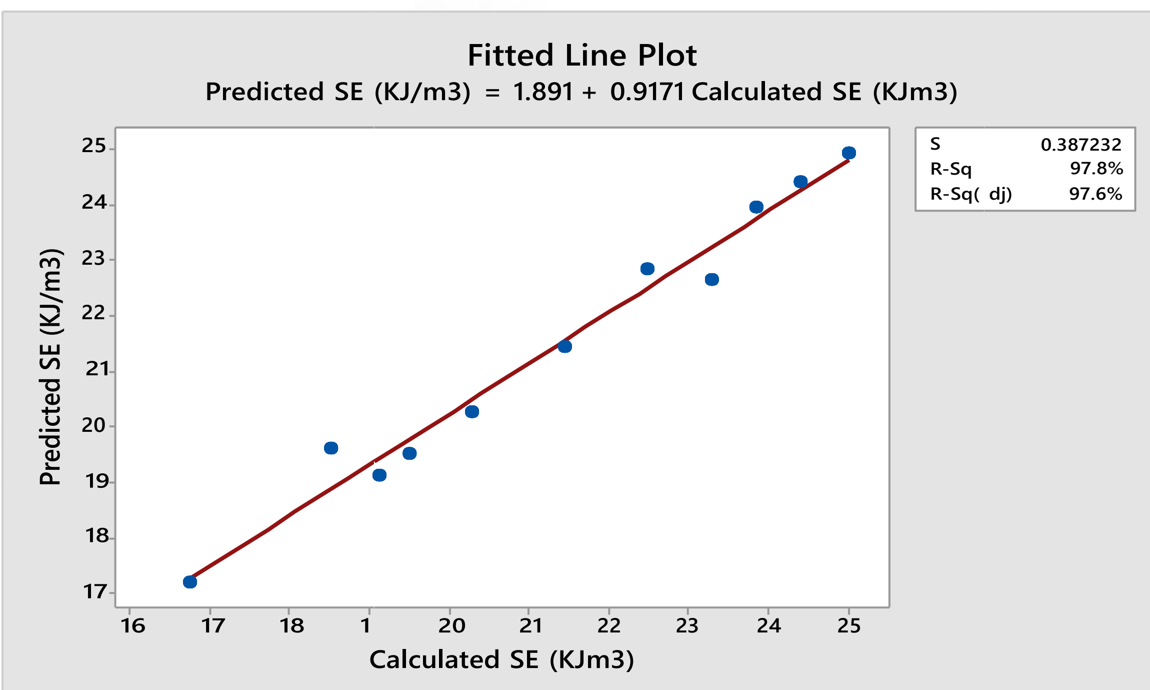

Figure 4.27
Scatter plot of Specific energy values predicted by ANN versus Measured values for 65° bit angle at 65°Attack angle

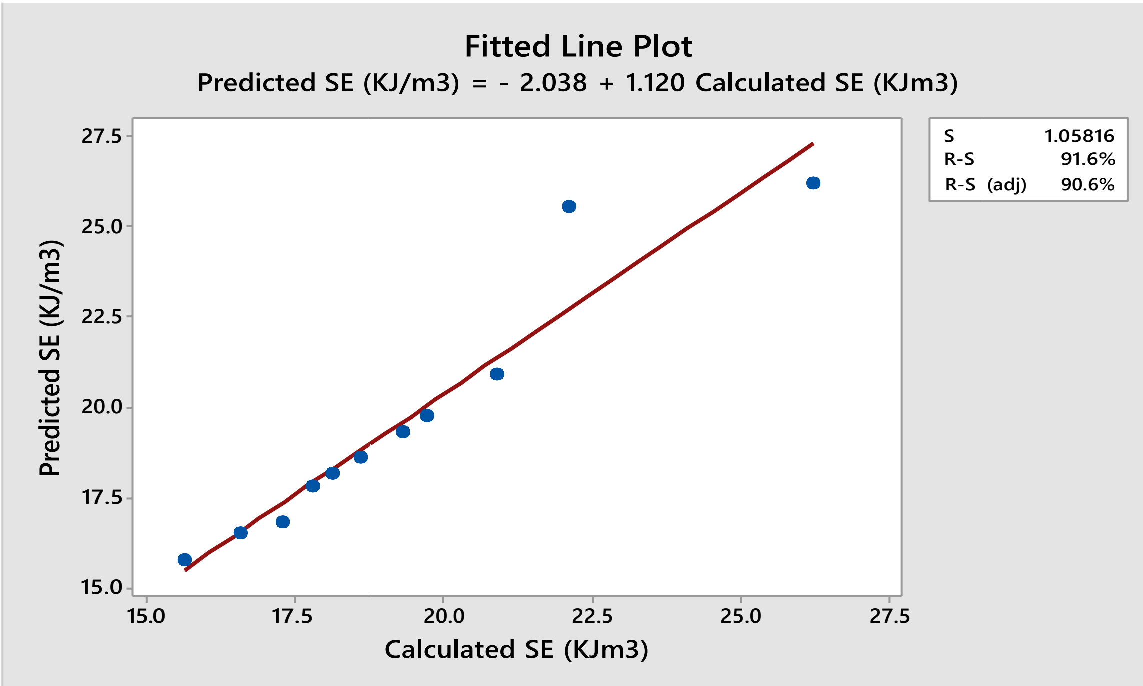

Figure 4.28

Scatter plot of Specific energy values predicted by ANN versus Measured values for 45° bit angle with 5mm wear at 45° Attack angle

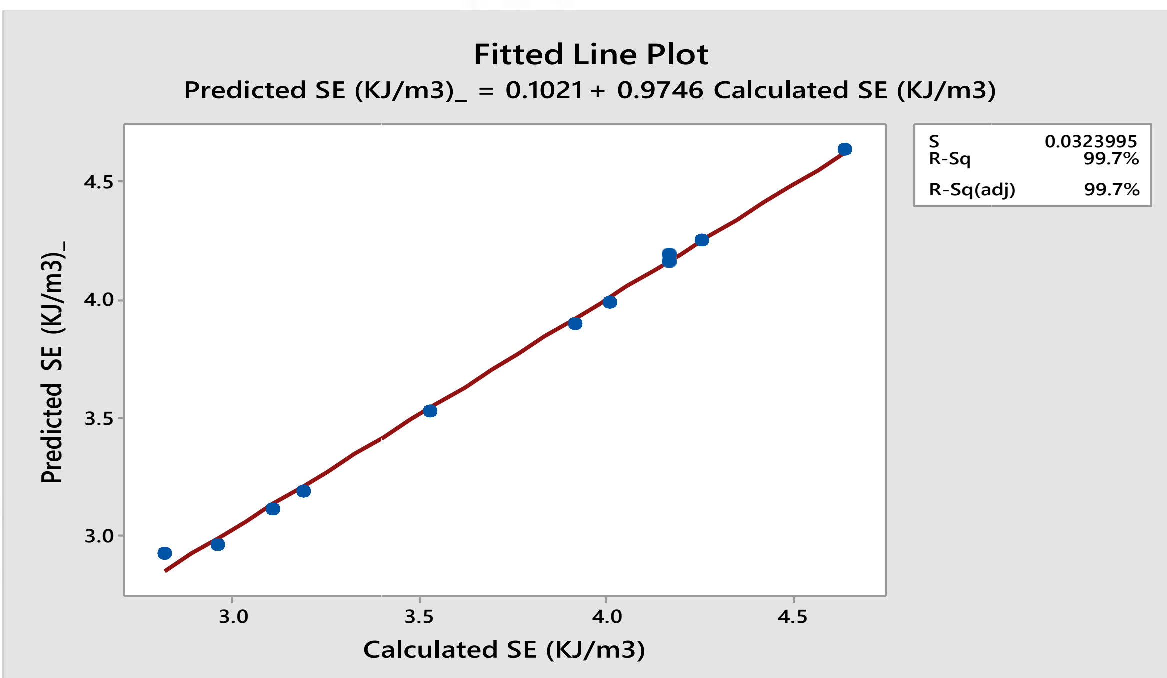

Figure 4.29

Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle with5mm wear at 45° Attack Angle

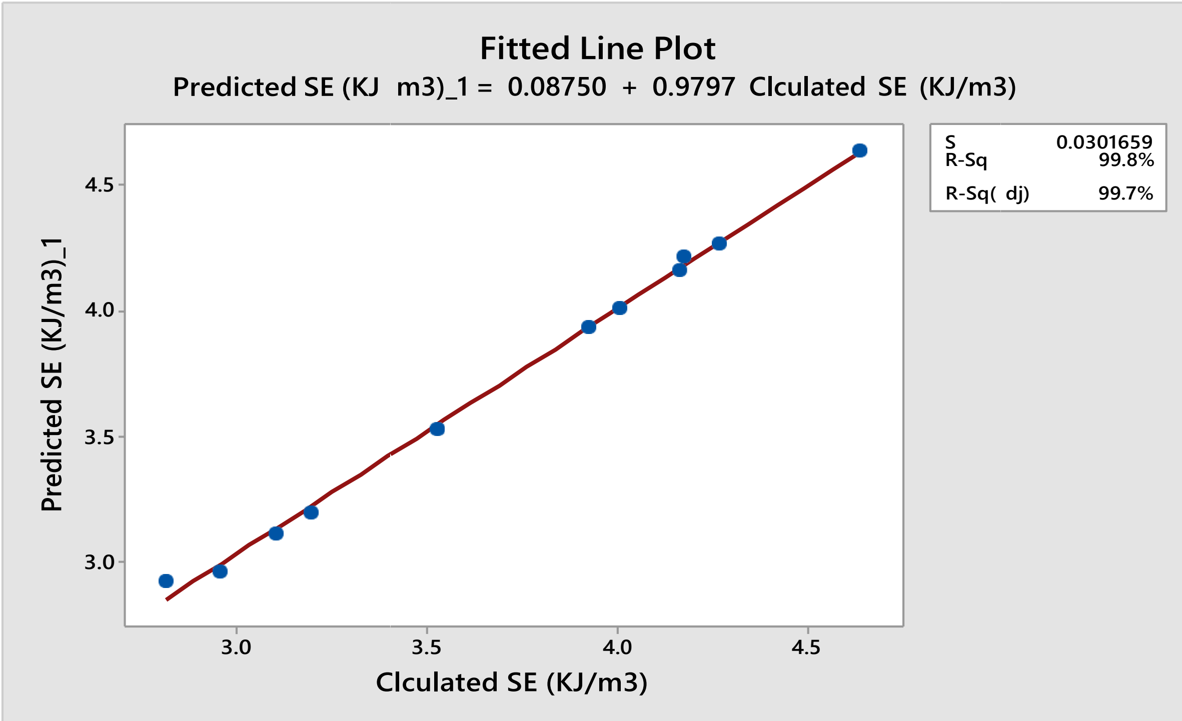

Figure 4.30
Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle with5mm wear at 45° Attack Angle

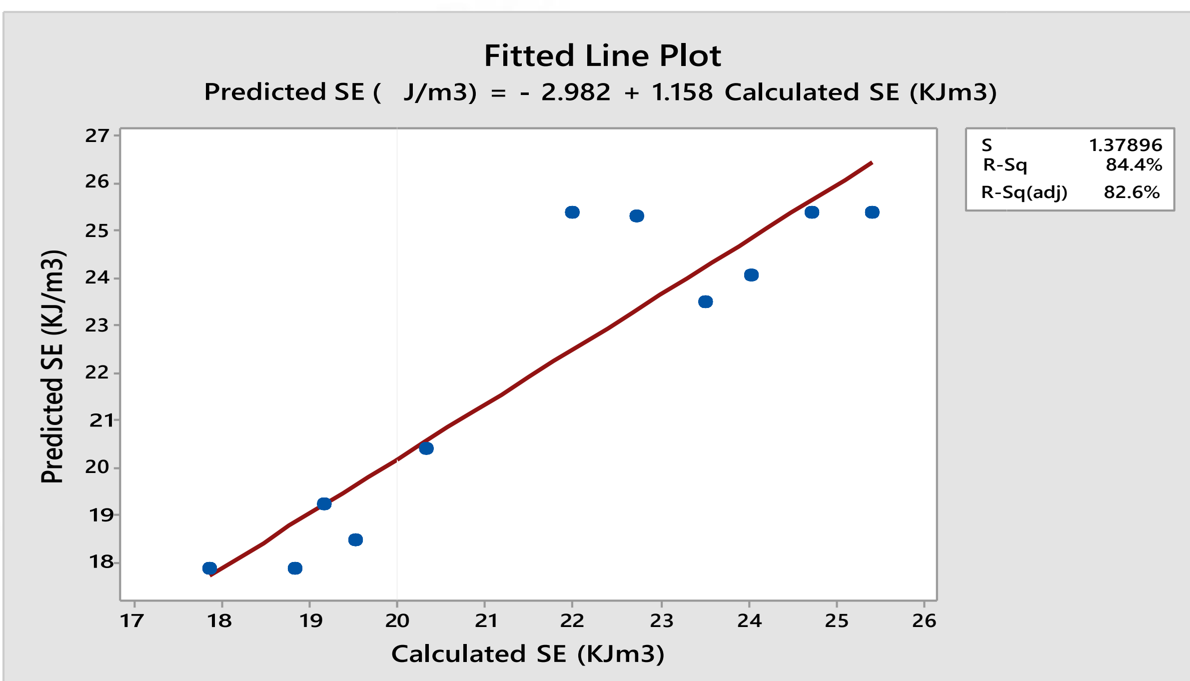

Figure 4.31
Scatter plot of Specific energy values predicted by ANN versus Measured values for 50° bit angle with5mm wear at 45° Attack Angle

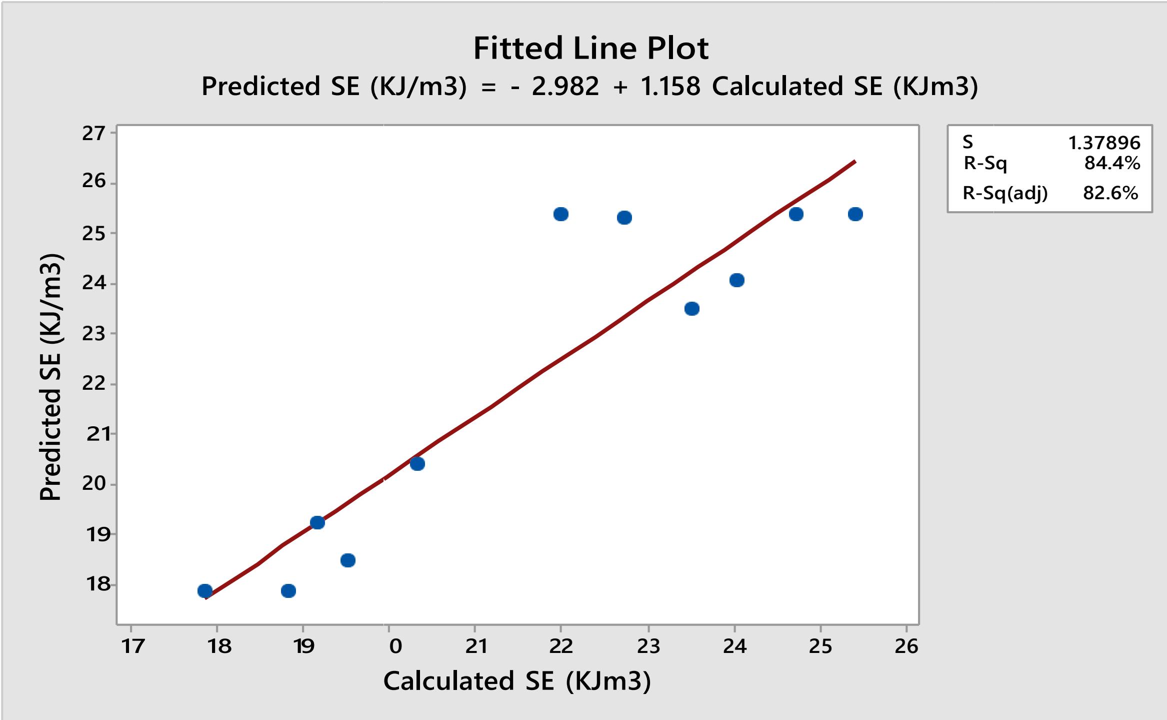

Figure 4.32
Scatter plot of Specific energy values predicted by ANN versus Measured values for 65° bit angle with 5mm wear at 45°Attack Angle

5. CONCLUSION

1. The experiment was conducted on 45°, 50°, 55°& 65° bit angle with 45°, 55°& 65° attack angles and the results were found good in 65° tip angle with 55° attack angle. Both the depth of cut and material cut is more for the measured specific energy.
2. Comparing the regression values of the plotted figure, the R^2 value predicted by ANN for Cutting le is more than 98% which is same as calculated value

Comparing with other R^2 value predicted by ANN for Cutting force and Specific energy at 45° attack angle is 95% and at 65° Attack angle is less than 90%.

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