Effect of ABS on the Mechanical Properties of PP/ABS Blends and Tensile Strength Using Taguchi Method

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Abstract

Polymer blend becomes one of the effective methods in the development of polymer industries. By applying this technique, it can help to control the environment and create new material with better performance from a net polymer. PP and ABS are the most extensively used commodity polymer due to their good mechanical properties. The aim of this study is to identify the injection molding parameters of PP and ABS such as melt temperature, mold temperature, injection pressure and holding pressure and is to inspect the mechanical properties of hybrid material between ABS and PP such as tensile strength, tensile modulus, and elongation. The relationship between the control parameters and the output response for the hybrid material has also been determined. The samples of PP/ABS blends were prepared via injection molding and have been categorized based on weight percentage. The parameter setting was selected based on the data available in the literature and suggested from resin supplier which is mold temperature, melt temperature, injection and holding pressure. The results showed that with the addition of ABS, the tensile stress is reduced causing the material becomes brittle. With the increasing content of ABS in PP/ABS blends, the tensile modulus will increase while the percentage of elongation in PP/ABS blends decreased. Holding pressure was the most significant effects for tensile strength in PP/ABS blends found from Signal to Noise Ratio (S/N) in the Taguchi Method.

Keywords: polymer blends, polypropylene (PP), acrylonitrile butadiene styrene (ABS)

1.0 Introduction

Polymer represents a wider range of properties and has numerous benefits over metallic, low prices and ease to the process**.** For these reasons, polymers continue to be among the most frequently used materials. Polymers divided into two types which are thermoplastics and thermosets.

Presently, polymer blending has been considered as an appropriate way for the development of newer polymeric materials with a better and extensive variety of properties. Both physical and mechanical properties of the polymer blends can be improved depending on the extent of adhesion at the interface and the how good the dispersion is one of phase into another (Alpesh, 2000).

Various types of plastic materials can be used to produce plastic material. In this study, Polypropylene (PP) and Acrylonitrile Butadiene Styrene (ABS) were chosen as the material for the experiments. PP and ABS are a common thermoplastic polymer, largely used in industrial application. Due to the number of its properties, the versatility of this material making it more cost-effective.

Nowadays, the whole world is concerning about the environmental issues, by applying the polymer blends can control the environment and create a new application from it (Yu, 2006). The purpose of blending PP with ABS is to get superior mechanical properties compared to pure polymers. There are several advantages of PP such as inexpensive material, high heat change in temperature and can process in many ways. However, PP has low impact properties which is one of the weaknesses of PP. With blending this polymer can improve the impact properties of PP because ABS is one of the rubbers toughen polymers that can be added to the PP matrix (Ganesh, 2018). ABS have good impact and chemical resistance, good strength and toughness, good low-temperature properties and high electrical resistance. Therefore, the blending of PP with ABS enhances positive properties and widening its scope of applications (Marianna, 2014).

Injection molding is one of the most common processes used to produce plastic parts. It is also one of the most important methods applied to manufacture varieties of plastic components. This method is based on the ability of thermoplastic materials to be softened by heat and it can be hardened when cooled. In the process of producing plastic products, the plastic in the form of pellets or granules is melted and then forced into the cavity of a closed mold which gives shape to the plastic. After sufficient time is given for the plastic to solidify (usually by cooling), the mold is opened and the part is ejected from the mold which is then closed again to repeat the cycle. (S. Kamaruddin, 2010).

Melt temperature, mold temperature, injection pressure, and holding pressure is select as a primary method in conducting the injection molding process. Based on the the data available in the literature and suggested from resin supplier, these parameters are selected because of its most influence to the quality product. The objectives of this study are:

i. To identify injection molding parameters of PP and ABS such as melt temperature, mold temperature, injection pressure and holding pressure.
ii. To inspect the mechanical properties of combination or hybrid material between ABS and PP such as tensile strength, tensile modulus, and elongation.
iii. To determine the relationship between the control parameters (melt temperature, mold temperature, injection pressure, and holding pressure) and the output response for the hybrid material.

2.0 Methodology

2.1 Material selection

The material used in this study is Polypropylene (PP) and (Acrylonitrile Butadiene Styrene) ABS. It is four samples after the material been weight and mixed. The sample had been categorized based on weight percentages in Table 1.

Table 1: Blends formulations

Blends	PP (wt %)	ABS (wt %)
A1	100	0
B1	90	10
C1	80	20
D1	70	30

2.2 Sample preparations

Dumbbell shaped is choose with dimension according to ASTM D638 standard where the length width (W) is 12.9mm, length overall (LO) 163 and thickness (T) is 3mm as shown in figure 1.

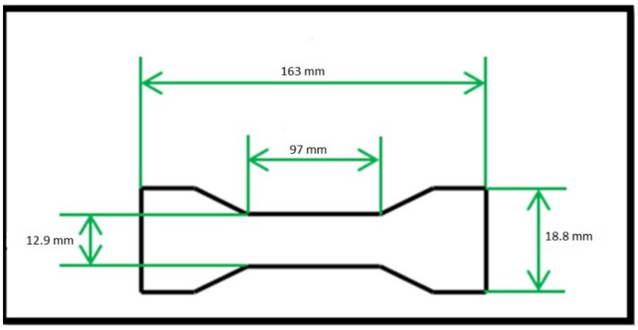

Figure 1: Dimension of sample

2.3 Selection of parameters

From the study, four important parameters have been emphasized, which is affecting the process as shown below. The process parameters were selected in light of the data available in the literature and suggested from resin supplier in Table 2.

Table 2: Process parameter for PP/ ABS

Factor	Parameter	Level 1 (Low)	Level 2 (Medium)	Level 3 (High)
A	Mold temperature (˚C)	30	30	30
B	Melting temperature (˚C)	220	220	220
C	Injection Pressure (Bar)	150	165	180
D	Holding Pressure (MPa)	45	54	65

2.4 Analysation of data using design of experiment (DOE)

Design of experiments is the most influential quality improvement method to decrease variation, improve process effectiveness and process capability. It is to determine the relationship between factors or parameter affecting a process and the result of the process. This data is required as it is vital element in order to increase the output in optimized level. The mechanical properties of the material are analysed by using Taguchi Method. Taguchi is used to identify the optimum parameter of the melt temperature, mould temperature, injection pressure and holding pressure.

2.5 Selection of orthogonal array

The selection of an appropriate orthogonal array (OA) depends on the total degrees of freedom of the parameters. The degree of freedom is defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. In this study, since each parameter has three levels the total degree of freedom (DOF) for the parameters are equal to 9. DOF for the OA should be greater or at least equal to those for the process parameters. Therefore, an $L9(3^4)$ orthogonal array is used in this study. Each row of this table represents an experiment with a different combination of parameters and their levels as shown in Table 3 and Table 4.

Table 3: L9(3^4) orthogonal array

No.of samples/Factors	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 4: Experimental layout using L9 Orthogonal Array.

No.of samples	Mold temperature (˚C)	Melting temperature (˚C)	Injection pressure (Bar)	Holding pressure (Bar)
1	30	220	150	45
2	30	220	165	54
3	30	220	180	64
4	30	220	165	64
5	30	220	180	45
6	30	220	150	54
7	30	220	180	54
8	30	220	150	64
9	30	220	165	45

2.6 Injection moulding

In this study**,** the injection molding machine is used to produce a specimen using a mold dumbbell-shaped. Before running the machine, injection molding machine, material (polypropylene and ABS) and mold need to be prepare.

2.7 Performing a tensile test

A tensile test is performed using a tensile tester (model: Instron 3366) with a 10kN computerized MTS model closed-loop servo-hydraulic system at a speed of 300mm/min under the room temperature. The specimens were loaded in tension until fracture. The results of this test were measured through at three measurements for each process. A stress-strain diagram was obtained from testing. The software was employed to control the procedure and continuously record the load and the compliance displacement as shown in Table 5.

Table 5: Test conditions

Load cell capacity	10kN
Test speed	300 mm/min
Test temperature	Room temperature
Software	Bluehill Universal

3.0 Results and discussions
3.1 Experimental result and analysis

Table 6: Result of tensile strength for unfilled PP, PP with 10%ABS, PP with 20% ABS and PP with 30% ABS

Sample	Mold temperature (˚C)	Melting temperature (˚C)	Injection pressure (Bar)	Holding pressure (Bar)	Tensile strength (Mpa) unfilled PP	Tensile strength (Mpa) PP +10 % ABS	Tensile strength (Mpa) PP +20 % ABS	Tensile strength (Mpa) PP + 30 % ABS
1	30	220	150	45	35.68	35.12	33.1	34.22
2	30	220	165	54	35.14	34.94	33.88	34.24
3	30	220	180	64	35.28	35.54	34.56	34.31
4	30	220	165	64	35.17	35.13	34.44	34.54
5	30	220	180	45	35.49	34.72	34.69	34.91
6	30	220	150	54	34.86	34.76	33.87	34.28
7	30	220	180	54	34.7	34.72	34.33	34.21
8	30	220	150	64	35.33	35.15	34.08	34.76
9	30	220	165	45	35.07	34.73	34.19	34.80

i. Signal to Noise Ratio (S/N Ratio)

The experimental results in Table 6 are then transformed into a signal to noise (S/N) ratio. S/N ratio which is 'Log' function of desired output serves as the objective function for optimization, help in data analysis and prediction of an optimal result. Taguchi recommends the use of the S/N ratio to measure the quality characteristics deviating from the desired value. The S/N ratio for each level of process parameters is computed based on the S/N analysis.

3.2 Effect of ABS content on the tensile strength of PP/ABS

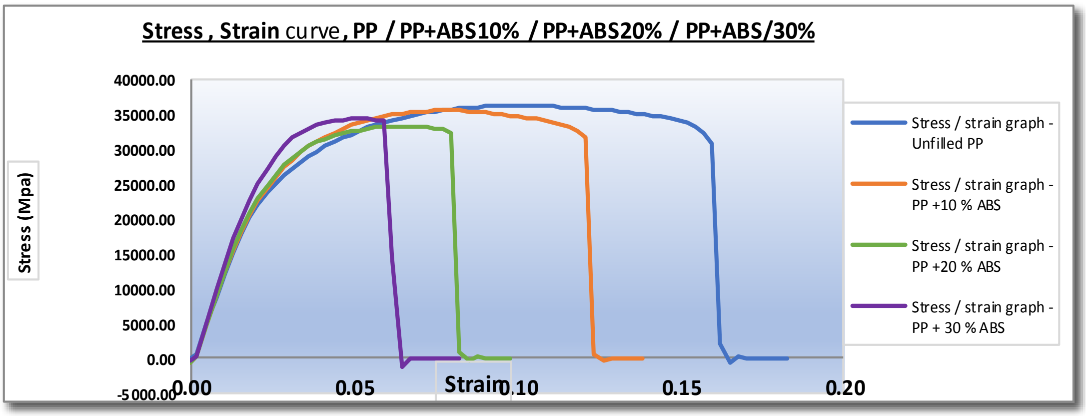

Figure 2: Stress vs strain curve

The stress-strain curve with different ratios, the result of increasing the weight percentage of % ABS (10%,20%, and 30%) are shown in Figure 2. The findings revealed that with the addition of ABS, the ductility is reduced causing the material to become brittle. This is seen as a change in the behavior in the tensile strength of PP/ABS. Another change in behavior is observed from the curves % of the sample in the begging of the load is in the elastic behavior whereby the plastic become deformed until it is capable of fracturing. It is seen from a pure PP sample that the maximum stress at fracture is 35.68 Mpa at a comparative rate with samples of polymer blends showing 35.12 Mpa with 10% ABS added varying to 33.1 Mpa with an addition of 20% ABS whereas addition of 30% showed 34.22 Mpa.

In his study (Alpesh, 2002) noted that blends containing 10-15% ABS indicated ductility change compared to blends which had 25% and more ABS added, resulted in a brittle character as the ABS addition caused the blends to break before the yield point. By increasing the ABS content and varying the work of yield with blend compositions, (Gupta, 1990) found that there was a similarity between yield stress decrease and the difference in impact strength. The researcher, therefore, concluded that the principal of toughening these blends justified shear yielding as the main mechanism. However, according to (Sateesh, 2014) in the case of the tensile strength of PP/ABS blends, there is not much improvement with the increased ABS content.

Table 7: The percentage of tensile strength reduction based on the addition of ABS

ABS %	1	% reduction	2	% reduction	3	% reduction	4	% reduction	5	% reduction	6	% reduction	7	% reduction	8	% reduction	9	% reduction
0	35.68	0	35.14	0	35.28	0	35.17	0	35.49	0	34.86	0	34.7	0	35.33	0	35.07	0
10	35.12	0.56	34.94	0.2	35.54	-0.26	35.13	0.04	34.72	0.77	34.76	0.1	34.72	-0.02	35.15	0.18	34.73	0.34
20	33.1	2.02	33.88	1.06	34.56	0.98	34.44	0.69	34.69	0.03	33.87	0.89	34.33	0.39	34.08	1.07	34.19	0.54
30	34.22	-1.12	34.24	-0.36	34.31	0.25	34.54	-0.1	34.91	-0.3	34.28	-0.41	34.21	0.12	34.76	-0.68	34.8	-0.61

3.3 Effect of ABS content on the modulus of PP/ABS blends

Table 8: Result of tensile modulus for unfilled PP, PP with 10%ABS, PP with 20% ABS and PP with 30% ABS

No. of samples	Mo T (˚C)	MT (˚C)	IP (bar)	HP (Bar)	Modulus (Mpa) unfilled PP	Modulus (Mpa) PP +10 % ABS	Modulus (Mpa) PP +20 % ABS	Modulus (Mpa) PP + 30 % ABS
1	30	220	150	45	1145.96	1231.64	1278.11	1489.40
2	30	220	165	54	1067.75	1298.45	1306.38	1495.82
3	30	220	180	64	1069.67	1334.22	1452.20	1529.17
4	30	220	165	64	1079.71	1304.30	1398.06	1521.09
5	30	220	180	45	1064.76	1307.50	1455.46	1530.5
6	30	220	150	54	1041.65	1315.77	1437.16	1512.28
7	30	220	180	54	1041.37	1313.93	1451.30	1518.1
8	30	220	150	64	1064.14	1333.84	1446.72	1519.39
9	30	220	165	45	1058.48	1363.65	1456.59	1498.66

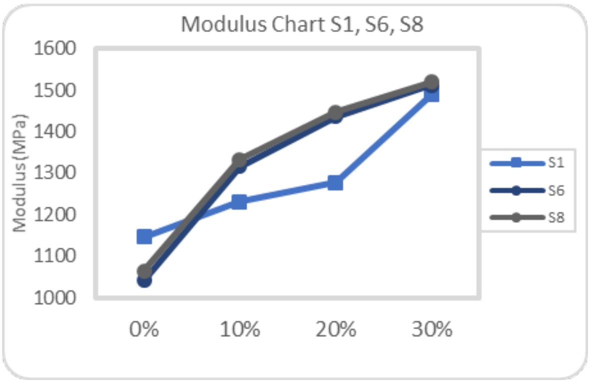

Figure 3: Modulus for sample 1,6 & 8 with injection pressure 150 bar

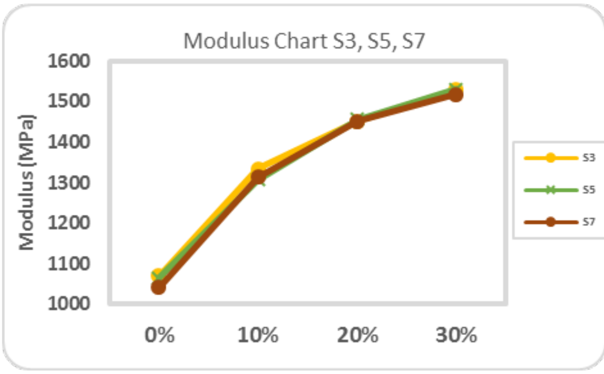

Figure 4: Modulus for sample 2,4 & 9 with injection pressure 165 bar

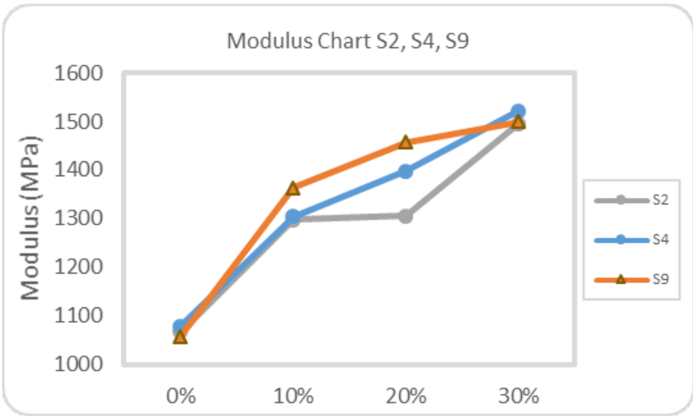

Figure 5: Modulus for sample 3,5 & 7 with injection pressure 180 bar

Increasing ABS ratios in the figure shows an increase in tensile modulus for sample 1 to 9 increase. There are 3 categories of injection molding parameters according to their different injection pressure and holding pressure. In his study, (Alpesh, 2000) made observations that because of the stiffening effect of ABS, there was an increase in tensile modulus when ABS was incorporated into PP. This is possibly due to the presence of higher modulus ABS particles in the dispersed phase.

3.4 Elongation

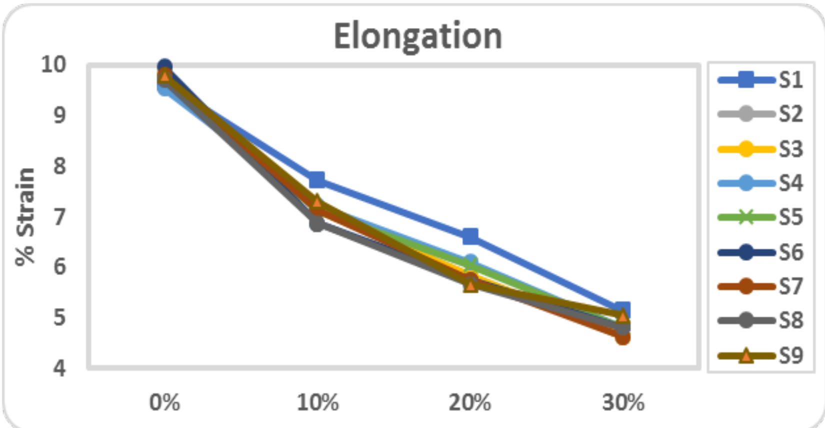

Figure 6: Comparing elongation between the 4 groups of the main polymers blends after addition of ABS

Table 9: Result of the percentage of strain for unfilled PP, PP with 10% ABS, PP with 20% ABS and PP with 30% ABS

No. of samples	MoT (˚C)	MT (˚C)	IP (bar)	HP (Bar)	Strain % unfilled PP	Strain % PP +10 % ABS	Strain % PP +20 % ABS	Strain % PP + 30 % ABS
1	30	220	150	45	9.65	7.73	6.61	5.15
2	30	220	165	54	9.96	7.13	6.27	5.15
3	30	220	180	64	9.79	7.13	5.84	4.64
4	30	220	165	64	9.54	7.22	6.10	4.90
5	30	220	180	45	9.79	7.13	6.04	4.81
6	30	220	150	54	9.96	6.87	5.75	4.81
7	30	220	180	54	9.79	7.13	5.67	4.64
8	30	220	150	64	9.71	6.87	5.67	4.62
9	30	220	165	45	9.79	7.38	5.67	5.06

The comparison of elongation for PP after the addition of ABS to the blends with the nine parameters is shown in Table 9. The data in the table show that with the addition of ABS to the PP/ABS blends, there is a decrease in elongation in his (Alpesh, 2000) made the observation that while poor impact strength was seen in PP with high elongation and also good resistance to chemicals and although was poor elongation with ABS, there was high impact strength.

i. Analysis of Data for Signal to Noise Ratio; PP with 10% ABS

The largest S/N ratio value of 31.0143 is seen at Sample 3 in the signal to noise ratio table. This sample has a mold temperature of 30˚C and melts temperature of 220˚C, both of which are constant. Its injection pressure is at level (180Mpa) and the holding pressure also at level 1 is (64Mpa). On the other hand, at sample 5 with an S/N ratio value of 30.8116 and the injection pressure at level 1(180Mpa) including the holding pressure at level 1(45 Mpa) is the smallest S/N ratio value. It is showing a good indication because as holding pressure increase the shear stress in the layers.

Table 10: Signal to noise ratios

No. of samples	M_oT	MT	IP	HP	Tensile strength (Mpa)	S/N ratio
1	30	220	150	45	35.12	30.9111
2	30	220	165	54	34.94	30.8665
3	30	220	180	64	35.54	31.0143
4	30	220	165	64	35.13	30.9136
5	30	220	180	45	34.72	30.8116
6	30	220	150	54	34.76	30.8216
7	30	220	180	54	34.72	30.8116
8	30	220	150	64	35.15	30.9185
9	30	220	165	45	34.73	30.8141

Table 11: Response table of S/N ratio for each level of each factor

Level	MoT	MT	IP	HP
1	30.9306	30.8787	30.8837	30.8456
2	30.8489	30.8655	30.8647	30.8332
3	30.8481	30.8833	30.8792	30.9488
Delta	0.0826	0.0178	0.0190	0.1156
Rank	2.0000	4.0000	3.0000	1.0000

As seen in the response table for signal to noise ratios, the highest influence affected by the tensile strength with the delta value 0.1156 is the holding pressure which is the first rank, indicating the higher the value, the better the tensile strength The second rank with the delta value of 0.0826 is mold temperature while injection pressure with the delta value of 0.0190 is the third rank and the fourth rank is melt temperature with the delta value of 0.0178. When the four parameters are analyzed the injection pressure has the smallest value. Ranked sequentially, the holding pressure shows the highest influence significantly affecting the tensile strength. The other parameters mold temperature, melt temperature, and injection pressure indicates influences of decreasing significance.

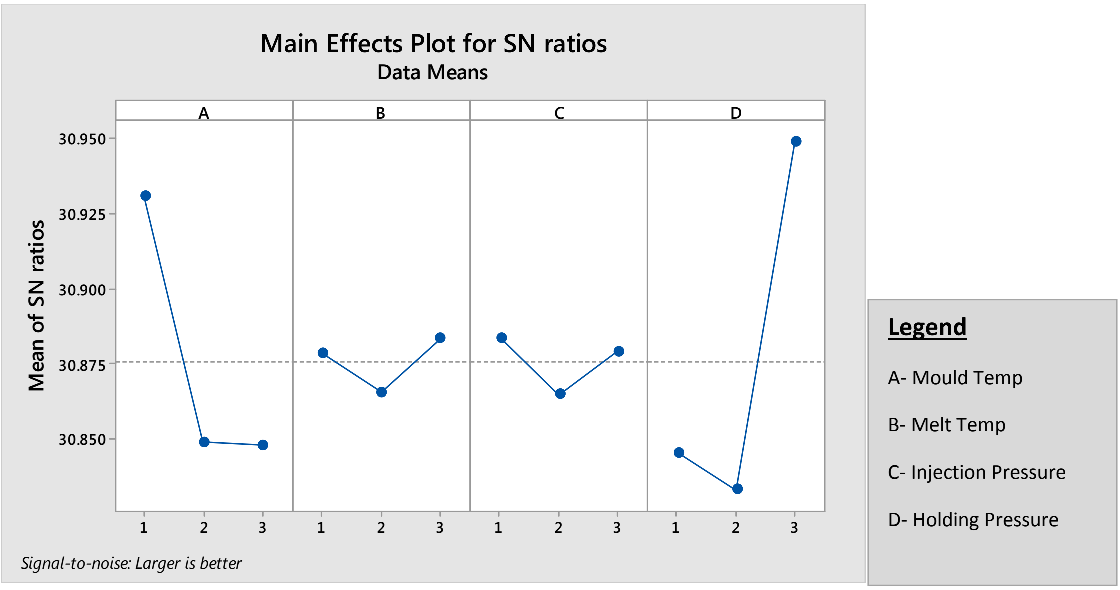

Figure 7: Main effects plot for S/N ratios

The characteristics used to determine the highest tensile strength as the ideal condition to study the optimum necessary for the injection molding parameter was the higher, the value the stronger the tensile strength. The trend of how each injection molding parameter responds to the tensile strength based on the principle the higher the strength, the better characteristics, is seen in the graph of main effect plot for S/N ratios. The best results shown in figure 7 are the control parameter factor of mold temperature at level 1(30˚C), melt temperature at level 2 (220˚C) injection pressure at level 1(150Mpa) and holding pressure at level 1 (64Mpa).

4.0 Conclusion

This study presents an experimental study of the mechanical properties (tensile test) of polymer blends PP/ABS. Several conclusions were obtained through the experiments which are in tensile strength, the results indicate that with the addition of ABS, there is a change in the behavior in the tensile strength of PP/ABS. The value of tensile strength decreases by increasing the percentage of ABS. In tensile modulus, increasing ABS ratios in the PP/ABS blends showed an increase in tensile modulus and with the addition of ABS to the polymer blends, there was a decrease in elongation of PP/ABS blends. The S/N ratio analysis has shown that the holding pressure shows the highest influence significantly affecting the tensile strength. The optimal combination of the PP with 10%ABS parameters in tensile strength was mold temperature at level 1(30˚C), melt temperature at level 2 (220˚C) injection pressure at level 1 (150Mpa) and holding pressure at level 1 (64Mpa). In this study, the maximum addition of ABS was 30% because it based on a previous study (Gupta, 1990) the result show there was no value for tensile strength for 40% and 50% ABS due to breaking occurs before reaching of yield peak.

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