Report on Heat Transfer Analysis of Thin Films

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by Devesh Pande (RA) and Meung J Kim (Professor)
Department of Mechanical Engineering, College of Engineering and Engineering Technology
Northern Illinois University, DeKalb, Illinois

Analysis of heat transfer in thin film of composite material

Inputs from the previous meeting

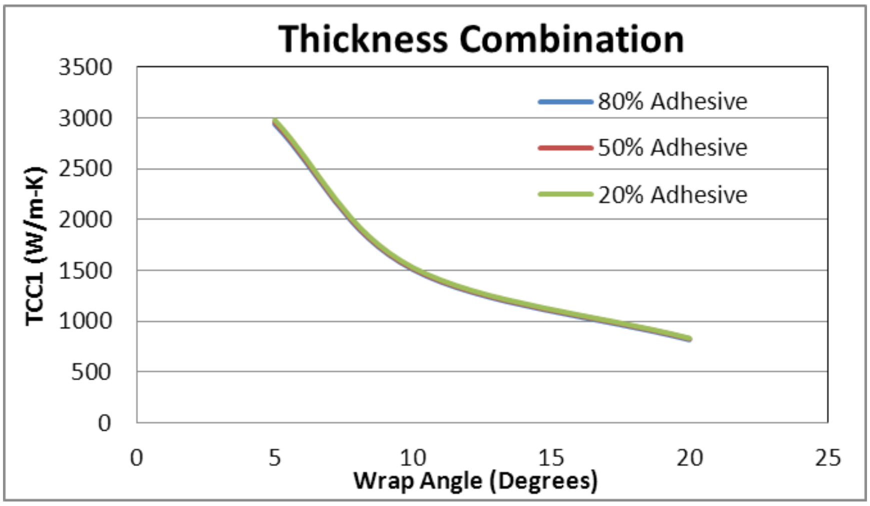
Suggestions were made to improve the specific heat of the backing and adhesive material within the operating range. In this report, the effects of different wrap angles on the thickness combination of backing and adhesive layer as well as the combination ratio of different materials in the backing layer are considered. In addition to these cases, the effect of changing the specific heat of which layer material has an effect on the temperature distribution more is also analyzed.

Case 1: Effect of different wrap angles for different thickness combination

The effect of different wrap angles on different thickness configurations of the backing and adhesive layer were considered in this case. The rotational speed of the roller was kept the same at 250 ft/min. The wrap angles that were considered were 5, 10 and 20 degrees. Due to this change in wrap angle, the contact time changed. The contact time for 10 degree wrap angle was estimated to be 0.036 seconds and that for 20 degree wrap angle was 0.072 seconds. TCC2 value was kept constant to 2000 W/m-K. Below are the observed results. If we observe the general trend of variation of TCC based on thickness configuration, we can see that the trend remains constant irrespective of the thickness configuration. This can be attributed to the fact that the layers are too thin and the heat capacities of HDPE and EMA are very similar.

Thickness of the Layer		**Wrap Angles (degree)**		
		5	**10**	**20**
% of EMA	**% of HDPE**	**TCC1 (W/m-K)**		
80	20	2940	1510	820
50	50	2960	1520	830
20	80	2980	1530	835

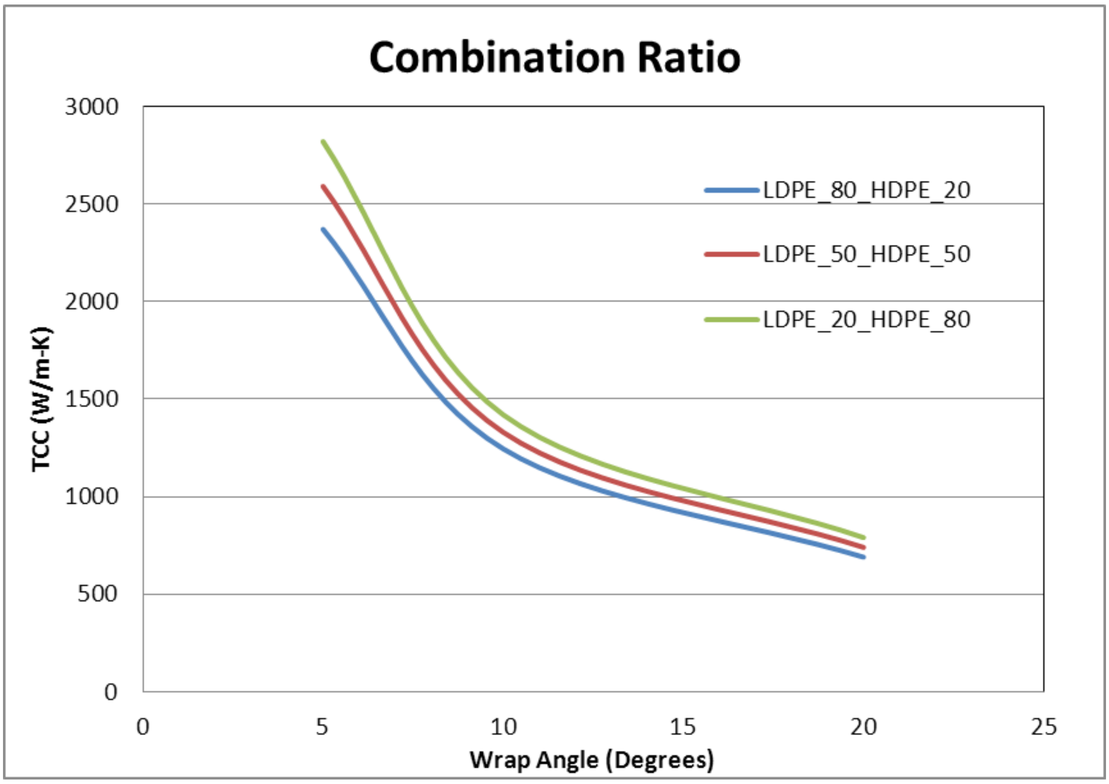
Table 1



Case 2: Effect of wrap angle and combination ratio on temperature distribution

In this case the effect of wrap angle on combination ratio of different materials is considered. LDPE and HDPE are the materials used. As the amount of higher specific heat material within the operating range like HDPE is increased in the backing layer, we see that the TCC value increases for each individual wrap angle value. This means that the window of operation will increase but if actual operation is considered, using LDPE in the backing layer would be better because this will lower the contact conductance value and will give the opportunity to use higher wrap angles. The trend remains the same for all the case. There is a threshold value of the wrap angle beyond which increasing the wrap angle has a lesser effect on the thermal contact conductance. Below are the observed results.

Composition of the Backing Layer		**Wrap Angles**		
		5	10	20
% of LDPE	**% of HDPE**	**TCC1 (W/m-K)**		
80	20	2370	1245	690
50	50	2590	1330	740
20	80	2820	1420	790



Effect of specific heats of individual materials on temperature distribution

It was important to understand the effect of individual specific heats of the materials and its effect on the temperature distribution or in other words specific heat of which layer affect the temperature distribution more was considered. Only two layers were considered in this case. The backing layer was made up of HDPE and adhesive layer was made up of EMA. The specific heat of each material was increased by 10, 50 and 100% while keeping the specific heat of the other material was kept constant. Actual as well as averaged specific heats were used to understand the distribution better.

Case 3: Using actual material properties

In this case the specific heats for individual materials were increased based on the specific heat values obtained from DSC. Below are the observations. We see that increasing the specific heat of the backing layer has a larger effect on the temperature distribution. This confirms the initial observation that backing layer acts as a gate layer. The effect seen below is not that significant because specific heats of HDPE and EMA are very similar in the operating range.

Increasing Specific heat of HDPE		
% Change	**TCC (w/m-K)**	**% Change**
Base TCC	2960	
10%	3120	5.405405405
50%	3750	26.68918919
100%	4570	54.39189189

Increasing Specific heat of EMA		
% Change	**TCC (w/m-K)**	**% Change**
Base	2960	
10%	3110	5.067567568
50%	3730	26.01351351
100%	4520	52.7027027

Using Constant specific heat values--Higher specific heat for backing layer

In order to understand the temperature distribution better, constant specific heats were used for both the backing layer and the adhesive layer. The specific heat of the backing layer was increased every time and its effect on temperature distribution was analyzed. The percentage changes in the thermal contact conductances for the backing layer were compared to the percentage change of the adhesive layer. It was found that increasing the specific heat of the backing layer has a larger impact on the temperature distribution than the adhesive layer.

Case 4: Same specific heat for backing and adhesive layer

In this case the specific heats for backing and adhesive layer were kept exactly the same and equal to 3000 J/kg-K. The effect of increasing the specific heat was observed. Below are the observed results. We can see that when the difference in the specific heat between the adhesive and the backing layer is zero, both the layer affect the temperature distribution nearly equally.

Increasing Specific heat of HDPE		
% Change	TCC (w/m-K)	% Change
Base	2760	
10%	2900	5.072463768
50%	3510	27.17391304
100%	4260	54.34782609

Increasing Specific heat of EMA		
% Change	TCC (w/m-K)	% Change
Base	2760	
10%	2890	4.710144928
50%	3480	26.08695652
100%	4210	52.53623188

Case 5: Using specific heat values as 3500 and 3000 J/kg-K

In this case the specific heat values used were 3000 and 3500 J/kg-K. At first the specific heat of backing layer is kept as 3500 J/kg-K and the specific heat of adhesive layer is kept as 3000 J/kg-K. After running the cases for 10%, 50% and 100% specific heat increase, the specific heats are interchanged for backing and adhesive layer so that exactly opposite cases are run. Below are the observed results. We can see a marked difference in the TCC values when higher specific heat materials are used. Also it can be observed that increasing the specific heat of backing layer would be beneficial than the adhesive layer

Increasing Specific heat of HDPE		
% Change	TCC (w/m-K)	% Change
Base	3000	
10%	3180	6
50%	3880	29.33333333
100%	4770	59

Increasing Specific heat of EMA		
% Change	TCC (w/m-K)	% Change
Base	3000	
10%	3170	5.666666667
50%	3850	28.33333333
100%	4710	57

Case 6: Using specific heat values as 4000 and 3000 J/kg-K

In this case the specific heat values used were 3000 and 4000 J/kg-K. Below are the observed results. We can see that the TCC values have increased when compared to the previous case. These two cases prove that increasing the specific heat of the backing layer would have a larger impact on the window of operation within the operating range.

Increasing Specific heat of HDPE		
% Change	TCC (w/m-K)	
Base	3250	% Change
10%	3450	6.153846154
50%	4230	30.15384615
100%	5250	61.53846154

Increasing Specific heat of EMA		
% Change	TCC (w/m-K)	% Change
Base	3250	
10%	3440	5.846153846
50%	4230	30.15384615
100%	5210	60.30769231

Summary of the Results:

When we look at the summary of the all the cases we have run we find that there is a linear relationship between TCC and specific heat. As the specific heat of backing layer is increased, a corresponding increase in the TCC value is seen. This is true for both backing as well as the adhesive layer though the difference is higher when specific heat of backing layer is increased. Research studies show that in polymer films, thermal conductivity starts playing a major role in heat transfer only above film thicknesses of 0.5 mm. For thinner films like the present case, it is the specific heat which has a larger impact and this has been proved from the graph.

Increasing the Specific heat of EMA			
Specific heat		**TCC**	**% increase in TCC**
Backing Layer	Adhesive Layer	(W/m-K)	(%)
3000	3000	2760	2.76
3000	3300	2890	2.89
3000	3500	3000	3
3000	3850	3170	3.17
3000	4000	3240	3.24
3000	4400	3440	3.44
3000	4500	3480	3.48
3000	5250	3850	3.85
3000	6000	4230	4.23
3000	7000	4710	4.71
3000	8000	5210	5.21

Increasing the Specific heat of HDPE			
Specific heat		**TCC**	**% increase in TCC**
Backing Layer	Adhesive Layer	(W/m-K)	(%)
3000	3000	2760	2.76
3300	3000	2900	2.9
3500	3000	3000	3
3850	3000	3180	3.18
4000	3000	3250	3.25
4400	3000	3450	3.45
4500	3000	3510	3.51
5250	3000	3880	3.88
6000	3000	4260	4.26
7000	3000	4770	4.77
8000	3000	5250	5.25

Conclusions and further actions:

1. Using different layer thickness for backing and adhesive layer may not play a major role in the temperature distribution since the layers are too thin. The effects of different wrap angles are similar for each of the cases.

2. Using higher specific heat material like HDPE in the backing layer will have larger effect on temperature distribution while using higher wrap angles.

3. Increasing the specific heat of backing as well as the adhesive material can affect the temperature distribution. However a higher effect can be seen if specific heat of backing layer is increased.

4. From the view point of operation, increasing specific heat of adhesive layer is better because low contact resistances can be used. However, the window of operation will be very narrow and will require a precise control over the lamination process.

5. In the second part of this phase, a new model will be developed for higher wrap angles. As the wrap angles become larger than 20 degree, the curvature effect will come in to picture and it will perhaps have a non-uniform temperature distribution through the layers.