not trivial. The custom test fixtures illustrated high-strain rates and biaxial stress states is sensitive to strain rate and stress states.

ASTM testing. with 2 in/min cross head speed, used for strain rate caused by a normal tensile test 30 in/in/sec, which is about 100 times the at the point of the impact can be as high as For a 3-foot drop event, the peak strain rate rates, under equal biaxial stress and under uniaxial stress, after which a stress state dependent material model was created. This is very important because the stress state stress state are different for each location on the pouch during the impact event. Accurately capturing the material behavior is very important because the strain rate and uniaxial stress, after which a stress state dependent model needs to accurately capture the failure propagation long after the initiation. For situations where the model was developed that captures the salient material behaviors. In previous cases 1, 3, and 4 the focus was on failure initiation. However, for the tear-opening simulation, the failure model needs to accurately capture the failure propagation long after the initiation. For situations where the film is exposed to long periods of thermal exposure, such as a retort, the material behavior often changes. It has been observed that the material ductility can reduce significantly and become much more sensitive to the load path, tearing force and environmental condition. This requires the development of the material model to be based on thermally processed materials. When this is done, experience indicates that the pouch tear-opening simulation can provide directional input to the design of the opening feature (Figures 7 and 10). 

Figure 7. Drop impact simulation

Figure 10. Tear-opening simulation – an off-line tearing dotted line

Case 6: Pouch Tear-Opening Simulation

Consumers become astounded when tear opening feature fails (Figure 10). It is not uncommon for a consumer to have to make a second or third try, or use scissors to fully open a pouch that does not contain a tear opening feature. Design tools can be used to understand the underlying physics that define the performance envelope of the package, avoiding costly and time consuming trial and error development.

Figure 9. Customized biaxial tensile test

Predictive Analysis Saves Time & Avoids Remark

Although challenging, it is possible to use modeling and simulation to support the development of flexible packaging. Accurately characterizing the film for the loading situation being considered is critical to success, and much more complex than with rigid packaging. However once it is characterized, predictive analysis tools can be used to understand the underlying physics that define the performance envelope of the package, avoiding costly and time consuming trial and error development.

Figure 11. Tear-opening simulation – an off-line tearing dotted line

Figure 12: Tear-opening simulation – a sight-line tearing

Sustainability is the Driver For Flexible Packaging

Sustainability is an important global environmental topic and a growing area of packaging-related innovation. With Asian and European markets leading the charge, the range of application of flexible packaging in the United States is expanding.

Light-weighting Primary Packages

One of the most important tenets of sustainability is light-weight primary packages. The ultimate light-weight packages are flexible pouches, provided they are not required to support any significant stacking type load. Innovations in film technologies have enabled the adaptation of flexibles into the very challenging application of battle, robot and micro-wave-ready food packaging.

Figure 13: Examples of flexible pouches in final industry

Modeling & Simulating Flexible Packaging Performance

The use of computer-based modeling and simulation tools to develop and optimize package designs has become more-mainstream for rigid packages among major consumer product, medical and packaging companies. These methods cover a wide range of manufacturing processes from injection/molding to extrusion to thermoforming to consumer handling. However, the application of computer-based simulation methods to the flexible domain is now. The flexibility of the pouch

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Case 1: Venting Seal Bar Design for Microwaveable and Retortable Pouches

One of the key challenges of the venting seal bar design is that the bond that is created needs to be strong enough to withstand high temperatures (~210°F) and pressures (15-25psig) in the retort sterilization process without leaking. In the presence of an overpressure, pressures (15-25psig) in the retort sterilization process can be generated due to the thermal expansion of the air/gas in the head-space of the pouch. This often occurs during the cook period of the retort cycle, when the temperature is highest (~250°F). SES has developed a proprietary algorithm, “Bi-Path,” to calculate the “state” of the gas in the headspace. An extended cooling period (~15 minutes) presents an additional challenge to the seal integrity due to the material’s creep behavior. The simulation in this case study focuses on the pouch seal bar integrity, generally similar to the venting design case (Case 1). Therefore, the bonding failure model is one of the key elements of the simulation; however, instead of generating a failure model at room temperature, the elevated temperature and time related creep effects must be taken into account. This analysis simulates the entire retort cooking to the cool down (Figure 6). The results determine the hot spot locations and provide a directional input, which the design team can use to size the seal bar and optimize the design.

Case 2: Stand-up Pouch Filling Simulation

The presentation of the empty pouch to the filler and heat sealing equipment is crucial in maintaining the efficiency of the line and minimizing downtime. The analysis of the pouch filling begun, followed by opening for filling, stand-up base opening, liquid/solid filling and heat sealing can be simulated.

Heat seal simulation

Vent design

Figure 2: “4-leaf clover” vent design style

Vent open (seal debonding)

Vent seal simulation

Case 3: Pouch Heat Sealing Simulation

The focus of this study is the making of the top seal (Figure 4). The objectives are to generate a top seal that is strong, leak-free, smooth (free of wrinkles), and D6862). The test samples can be easily extracted from the side seals of representative or prototype pouches and the test can be performed using a typical tensile test machine.

The presentation of the empty pouch to the filler and heat sealing equipment is crucial in maintaining the efficiency of the line and minimizing downtime. The analysis of the pouch filling begun, followed by opening for filling, stand-up base opening, liquid/solid filling and heat sealing can be simulated.

Case 4: Retort Sterilization Simulation

Depending on the retort sterilization process, high internal pressure can be generated due to the thermal expansion of the air/gas in the head-space of the pouch. This often occurs during the period of the retort cycle, when the temperature is highest (~250°F). SES has developed a proprietary algorithm, “Bi-Path,” to calculate the “state” of the gas in the headspace. An extended cooling period (~15 minutes) presents an additional challenge to the seal integrity due to the material’s creep behavior. The simulation in this case study focuses on the pouch seal bar integrity, generally similar to the venting design case (Case 1). Therefore, the bonding failure model is one of the key elements of the simulation; however, instead of generating a failure model at room temperature, the elevated temperature and time related creep effects must be taken into account. This analysis simulates the entire retort cooking to the cool down (Figure 6). The results determine the hot spot locations and provide a directional input, which the design team can use to size the seal bar and optimize the design.

Case 5: Pouch Drop Impact Simulation

Package failure resulting from dynamic events, such as the dropping of a filled pouch can be captured by simulation. Again, the material failure model for the film is of paramount importance to the completion of a successful simulation.
One of the key challenges of the venting seal bar design is that the bond that is created needs to be strong enough to withstand high temperatures (~250°F) and pressure (4-5 psig). The simulation of the retort and a representative pouch shape, prior to filling. High-speed video learning, similar methods were used to develop alternative grip locations to mitigate wrinkling.

Case 2: Stand-up Pouch Filling Simulation

The presentation of the empty pouch to the filler and heat sealing equipment is crucial in maintaining the efficiency of the line and minimizing downtime. The analysis of the pouch filling process, beginning with holding, followed by opening for filling, stand-up base opening, liquid/fold filling and heat sealing can be simulated.

Case 3: Pouch Heat Sealing Simulation

The focus of this study is the making of the top seal. The objective is to generate a top seal that is strong, leak-free, smooth (free of wrinkles), and D6862). The test samples can be easily extracted with different peeling angles (ASTM D1876, D3330, and D6862). The test samples can be easily extracted from the side seals of representative or prototype pouches and the test can be performed using a typical tensile test machine.

Case 4: Retort Sterilization Simulation

Depending on the retort sterilization process, high internal pressure can be generated due to the thermal expansion of the air/gas in the headspace of the pouch. This often occurs during the cook period of the retort cycle, when the temperature is highest (~200°F). SES has developed a proprietary algorithm, “Bi-Path,” to calculate the stress engineering services.

Figure 6: Pouch retort sterilization simulation

Material’s creep behavior. The simulation in this case study successfully captured a wrinkle caused by improper pressure transfer grips (Figure 5). Based on this initial learning, similar methods were used to develop alternative grip locations to mitigate wrinkling.

Case 5: Pouch Drop Impact Simulation

Package failures resulting from dynamic events, such as the dropping of a filled pouch can be captured by simulation. Again, the material failure model for the film is of paramount importance to the completion of a successful simulation.

Figure 7: Package failure resulting from dynamic events, such as the dropping of a filled pouch can be captured by simulation.

Figure 8: Stresses generated by a filled pouch impacting a hard surface.
Case 1: Venting Seal Bar Design for Microwaveable and Retortable Pouches

One of the key challenges of the venting seal bar design is that the bond that is created needs to be strong enough to withstand high temperatures (~250°F) and pressures (15-25 psig) in the retort sterilization process without leaking (in the presence of an overpressure). The bond needs to withstand high temperatures (~250°F) and pressures (15-25 psig) for 60-90 seconds of microwave heating to initiate the venting (food temperature ~210°F and pouch internal pressure 4-5 psig).

When modeling this behavior, however, the main difficulty is the development of an adequate debonding initiation and propagation model (a failure model, in simulation terminology). A reasonable failure model can be generated and calibrated through peeling tests with different peeling angles (ASTM D1876, D3330, and D4862). The test samples can be easily extracted from the side seals of representative or prototype pouches and the test can be performed using a typical tensile test machine.

Once the heat-seal debonding failure model is generated, the simulation of the retort and representative microwave process simulation can be completed. The nonlinear heat transfer analysis of a commercial pouch (Figure 2) predicts the vent should open/break at 4.2 psig, while the test average is 4.5 psig.

When modeling this behavior, however, the main difficulty is the development of an adequate debonding initiation and propagation model (a failure model, in simulation terminology). A reasonable failure model can be generated and calibrated through peeling tests with different peeling angles (ASTM D1876, D3330, and D4862). The test samples can be easily extracted from the side seals of representative or prototype pouches and the test can be performed using a typical tensile test machine.

When modeling this behavior, however, the main difficulty is the development of an adequate debonding initiation and propagation model (a failure model, in simulation terminology). A reasonable failure model can be generated and calibrated through peeling tests with different peeling angles (ASTM D1876, D3330, and D4862). The test samples can be easily extracted from the side seals of representative or prototype pouches and the test can be performed using a typical tensile test machine.

Case 2: Stand-up Pouch Filling Simulation

The presentation of the empty pouch to the filler and heat sealing equipment is crucial in maintaining the efficiency of the line and minimizing downtime. The analysis of the pouch filling line, beginning with bottle feed, followed by opening for filling, liquid/fold filling and heat sealing can be simulated.

Transferring the partially formed package from unit op to unit op is modeled. The analysis in Figure 3 can be used to determine the optimal size of the side suction cups, the magnitude of the air pressure blist to open the package for filling and grip locations/algorithm to transfer the pouch. The fill capacity of the pouch is calculated based on the three-dimensional pouch shape, prior to filling. High-speed video has been used to evaluate and validate the methods used to approximate these critical behaviors, with good success.

Case 3: Pouch Heat Sealing Simulation

The focus of this study is the making of the top seal (Figure 4). The objective is to generate a top seal that is strong, leak-free, smooth (free of wrinkles), has minimal air or liquid pockets and is free of product contamination. To maximize the pouch filling capacity, the top of the pouch is often in an oval shape prior to being transferred to the heat sealing station.

Clamping a three-dimensional flexible seal opening into a two dimensional flat top seal without wrinkles is not trivial. The simulation model in this case study successfully captured a wrinkle caused by improper gripping (Figure 5). Based on this initial learning, similar methods were used to develop optimal gripping locations to mitigate wrinkling.

Case 4: Retort Sterilization Simulation

Depending on the retort sterilization process, high internal pressure can be generated due to the thermal expansion of the air/gas in the headspace of the pouch. This often occurs during the cook period of the retort cycle, when the temperature is highest (~200°F). SES has developed a proprietary algorithm, “Bi-Path,” to calculate the stress in the material’s creep behavior. The simulation in this case study focuses on the pouch seal bar integrity, generally similar to the venting design case (Case 1). Therefore, the bonding failure model is one of the key elements of the simulation; however, instead of generating a failure model at room temperature, the elevated temperature and time related creep effects must be taken into account. This analysis simulates the entire retort cooking to the cool down (Figure 6). The results determine the hot spot locations and provide a directional input, which the design team can use to size the seal bar and optimize the design.

Case 5: Pouch Drop Impact Simulation

Package failure resulting from dynamic events, such as the dropping of a filled pouch can be captured by simulation. Again, the material failure model for the film is of paramount importance to the completion of a successful simulation.

**Figure 1: Customized high strain rate tensile test machine and test data**
However, unlike cases 1 and 4, the critical material performance attributes are ductility under high-strain rates loading and ductility under biaxial stress. For a 3-foot drop event, the peak strain rate at the point of impact can be as high as 30 in/in/sec, which is about 100 times the strain rate caused by a normal tensile test with 2 in/min cross head speed, used for ASTM testing.

In general, plastic-composite films are very sensitive to strain rate and stress states. Characterizing the pouch film properties at high-strain rates caused by a normal tensile test and uniaxial stress, after which a stress state dependent material model was created. This requires the development of the material model needs to accurately capture the failure propagation long after the initiation. For situations where the film is exposed to long periods of thermal exposure, such as a retort, the material behavior often changes. However, for the tear-opening simulation, the failure and the height at which it occurs is done, experience indicates that the simulation techniques can be used to understand the underlying physics that define the performance envelope of the package, avoiding costly and time consuming trial and error development.

In Figures 7 and 8 have been used to generate the specific data needed to characterize the film performance. The tests were performed at various strain rates, under equal biaxial stress and under uniaxial stress, after which a stress state dependent material model was created. This is very important because the stress state and stress state are different for each location on the pouch during the impact event. Accordingly capturing the material behavior is crucial in reliably predicting the location of the failure and the height at which it occurs (Figure 9).

Case 6: Pouch Tear-Opening Simulation

Consumers become annoyed when tear opening feature fail (Figure 10). It is not uncommon for a consumer to have to make a second or third try, or use scissors to fully open a pouch that does not contain any packaging tension. Computational methods can be used to predict the performance of tear strip opening features, provided a material model is developed that captures the salient material behaviors. In previous cases 1, 3, 4 and 5 the stress was on failure initiation. However, for the tear-opening simulation, the failure model needs to accurately capture the failure propagation long after the initiation. For situations where the film is exposed to long periods of thermal exposure, such as a retort, the material behavior often changes. It has been observed that the material ductility can reduce significantly and become much more sensitive to the load path, tearing force and top seal variation. This requires the development of the material model to be based on thermally processed materials. When this is done, experience indicates that the pouch tear-opening simulation can provide directional input to the design of the opening feature (Figures 11 and 12).

Figure 10: Tear-opening simulation – an off-line tearing dotted line

Predictive Analysis Saves Time & Avoids Rework

Although challenging, it is possible to use modeling and simulation to support the development of flexible packaging. Accurately characterizing the film for the loading situation being considered is critical to success, and much more complex than with rigid packaging. However once its characterized, predictive analysis tools can be used to understand the underlying physics that define the performance envelope of the package, avoiding costly and time consuming trial and error development.

Sustainability is an important global environmental topic and a growing area of packaging-related innovation. With Asian and European markets leading the charge, the range of application of flexible packaging in the United States is expanding.

Light-weighting Primary Packages

Case 1: Pouch Tear-Opening Simulation

Light-weighting primary packages is to light-weight primary packages. The ultimate light-weight packages are flexible pouches, provided they are not required to support any significant stacking-type load. Innovations in film structures have enabled the adaptation of flexibles into the very challenging applications of hotfill, retort and micro-wave-ready food packaging.

Modeling & Simulating Flexible Packaging Performance

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Figure 1: Pouch tear-opening simulation

Figure 2: Drop impact simulation

Figure 3: Tear-opening simulation – a sight-line tearing

Figure 4: Customized biaxial tensile test

Figure 5: Drop impact simulation

Figure 6: Catheterized bi-axial test

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Sustainability is the Driver For Flexible Packaging

Sustainability is one of the most important drivers of sustainability is to light-weight primary packages. The ultimate light-weight packages are flexible pouches, provided they are not required to support any significant stacking-type load. Innovations in film structures have enabled the adaptation of flexibles into the very challenging applications of hotfill, retort and micro-wave-ready food packaging.

Modeling & Simulating Flexible Packaging Performance

The use of computer-based modeling and simulation tools to develop and optimize package designs has become more-or-less mainstream for rigid packagings among major consumer product, medical and packaging companies. These methods cover a wide range of manufacturing processes from injection/mold modeling, filming, folding, stacking, manufacturing to consumer handling. However, the application of computer-based simulation methodology to the flexible domain is new. The flexibility of the pouch material in bending, often introduces structural insta- bilities, wrinkles and complex contact situations that are very challenging to simulate. Case studies that follow demonstrate the current simulation technol- ogy’s readiness and predictive capability in flexible packaging applications.
not trivial. The custom test fixtures illustrated high-strain rates and biaxial stress states is sensitive to strain rate and stress states. In general, plastic/composite films are very strain rate caused by a normal tensile test and simulation of the opening feature (Figures 11 and 12). It has been observed that the material ductility can change significantly and become much more sensitive to the load path, tearing force and high deformation. This requires the development of the material model to be based on thermally processed material. Often, it is done, experience indicates that the punch tear-opening simulation can provide directional input to the design of the opening feature (Figures 11 and 12).

Case 6: Punch Tear-Opening Simulation

Consumers become annoyed when tear opening feature fails (Figure 10). It is not uncommon for a consumer to have to make a second or third try, or in some cases to fully open a pouch that does not contain any packaging content. Computation- tion methods can be used to predict the performance of tear opening features, provided a material model is developed that accurately captures the salient material behaviors. In previous cases 1, 2 and 6, the stress was in uniaxial tension. However, for the tear-opening simulation, the failure model needs to accurately capture the failure propagation long after the initiation. For situations where the film is exposed to long periods of thermal exposure, such as a retort, the material behavior often changes. It has been observed that the material ductility can change significantly and become much more sensitive to the load path, tearing force and high deformation. This requires the development of the model material to be based on thermally processed material. Often it is done, experience indicates that the punch tear-opening simulation can provide directional input to the design of the opening feature (Figures 11 and 12).

Predictive Analysis Saves Time & Avoids Rework

Although challenging, it is possible to use modeling and simulation to support the development of flexible packaging. Accurately characterizing the film for the loading situation being considered is critical to success, and much more complex than with rigid packaging. However, once its characterized, predictive analysis tools can be used to understand the underlying physics that define the performance envelope of the package, avoiding costly and time consuming trial and error development.

Sustainability is the Driver For Flexible Packaging

Sustainability is an important global environmental topic and a growing area of packaging-related innovation. With Asian and European markets leading the charge, the range of application of flexible packaging in the United States is expanding.

Light-weighting Primary Packages

One of the most important levels of sustainability is to lightweight primary packages. The ultimate lightweight packages are flexible pouches, provided they are not required to support any significant loading. Trade-off. Innovations in film technology have enabled the adaptation of flexibles into the very challenging application of hotfill, retort and microwave-ready food packaging.

Modeling & Simulating Flexible Packaging Performance

The use of computer-based modeling and simulation tools to develop and optimize package designs has become more-or-less mainstream for rigid packaging among major consumer product, medical and packaging companies. Those methods cover a wide range of manufacturing processes from injection/ blow molding, blown film extrusion and form filling to consumer handling. However, the application of computer-based simulation methods to the flexible domain is new. The flexibility of the pouch material in bending, often introduces structural insta- bilities, wrinkles and complex contact situations that are very challenging to simulate. Case studies that follow demonstrate the current simulation technol- ogy’s readiness and predictive capability in flexible packaging applications.

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