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TITRE
Analysis of welding problem and cracking of bolt hole that caused two leakage issues of C84E backlight in PSA

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Laboratoire/Service: Ingénieur qualité

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Abstract
This article mainly introduce two serious incidents happened in the PSA Rennes. The first one is about welding problem that lead to leakage of water in the light. The second is about bolt hole cracking problem that lead to leakage of water. The analysis, the possible reasons, the plan of action and the personal discussion are included in the article. For the first problem is thought to be caused by the badly adjusting of the dimension of z when they were heating the housing and lens. The condition of both part of melting are different then made the welding condition bad and the the connection strength weak. The second problem is concluded that it is caused by trapping gas in the material when injecting the material (ABS/PC). The structure is not perfect for injection so some improvements are implemented. Some analysis that are not the reason of the problem this time are also done and mentioned in the article.
Keywords: Welding problem; Cracking problem

Résumé
Cet article présente principalement deux incidents graves survenus au PSA Rennes. Le premier concerne les problèmes de soudage qui entraînent une fuite d'eau dans le feu. Le second concerne le problème de fissuration des trous de boulons qui entraîne une fuite d'eau. L'analyse, les raisons possibles, le plan d'action et la discussion personnelle sont inclus dans l'article. On pense que le premier problème est causé par le mauvais ajustement de la dimension de z lorsqu'ils chauffaient le boîtier et la lentille. L'état des deux parties de la fusion est différent, ce qui rend l'état de soudage mauvais et la force de connexion faible. Le deuxième problème est conclu qu'il est causé par le piégeage de gaz dans le matériau lors de l'injection du matériau (ABS/PC). La structure n'est pas parfaite pour l'injection, certaines améliorations sont donc mises en œuvre. Certaines analyses qui ne sont pas la cause du problème cette fois-ci sont également effectuées et mentionnées dans l'article.
Mots clés: Problème de soudage; Problème de fissuration

1. Welding problem

Introduction 1

List of the incidents happened in PSA Rennes

N	Incident List	Part type	Batch/Shift	Customer complaint	Confirmation
1	QEC CNJ 2020 12	Fender light RH	2019.8.6 day shift	Leakage defect	Welding issue
2	QEC CNJ 2020 17	Fender light RH	2019.8.5 day shift	Leakage defect	Welding issue
3	QEC CNJ 2020 24	Fender light RH	2019.8.5 day shift	Leakage defect	Welding issue
4	QEC CNJ 2020 24	Fender light RH	2019.8.4 day shift	Leakage defect	Welding issue
5	QEC CNJ 2020 26	Fender light RH	2019.8.6 day shift	Leakage defect	Welding issue
6	QEC CNJ 2020 36	Fender light RH	2019.8.6 day shift	Leakage defect	Welding issue

Remark: *QEC « End of life Product or Material » A type of incident after the piece installed on the vehicle.*

For the 6 issues, all are the leakage defect caused by the bad welding quality. For the 6 lights, the housing and the lens were separated in a certain part in the welding joint.

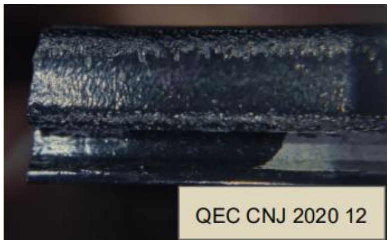
First inspection of these bad lights

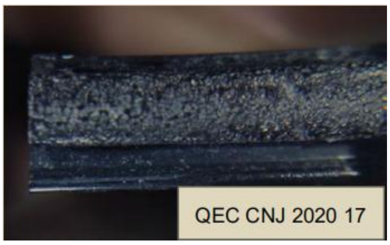
N	Appearance	Destructive	Welding height	Judgment
QEC CNJ 2020 12	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect
QEC CNJ 2020 17	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect
QEC CNJ 2020 24 #1	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect
QEC CNJ 2020 24 #2	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect
QEC CNJ 2020 26	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect
QEC CNJ 2020 36	Separated from welding joint	Smooth at welding joint, no lens material at housing surface	Circle is nonuniform	Welding defect

After the first inspection of the housing welding line, all the separated part welding line are smooth and no lens material left over the housing surface.

Destructive test result

Each photo of the incident light part welding joint：Figure. 1. Incident QEC 12, Figure. 2. Incident QEC 17, Figure. 3. Incident QEC 24 1#, Figure. 4. Incident QEC 24 2#, Figure. 5. Incident QEC 26, Figure. 6. Incident QEC 36.





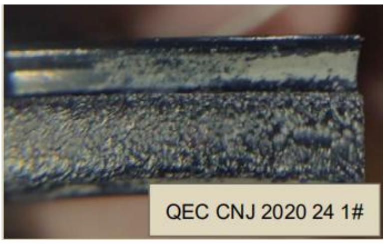
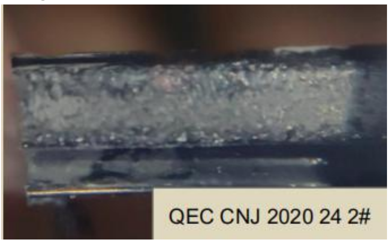
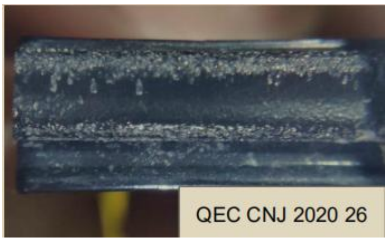


Figure. 1. Incident QEC 12 Figure. 2. Incident QEC 17 Figure. 3. Incident QEC 24 1#





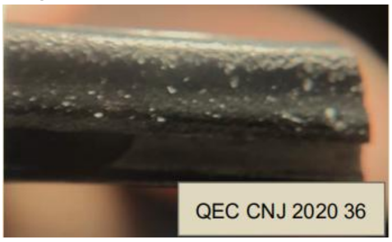


Figure. 4. Incident QEC 24 2# Figure. 5. Incident QEC 26 Figure. 6. Incident QEC 36

From the surface inspection, the result and conclusion is as follow:

Appearance:

1. For the 6 defect lights from PSA Rennes, the lens and housing are separated from the welding joint.
2. From the macroscopic side : the surface of the housing welding joint is smooth.
3. There is no other material left over the housing welding line.

Conclusion: The welding quality are unqualified.

Welding quality judgment standard :

Here is a figure. 7. that shows the welding problem. After the welding, because of some reasons unknown, the welding force is not strong enough which makes the lens and the housing separated from the welding joint.

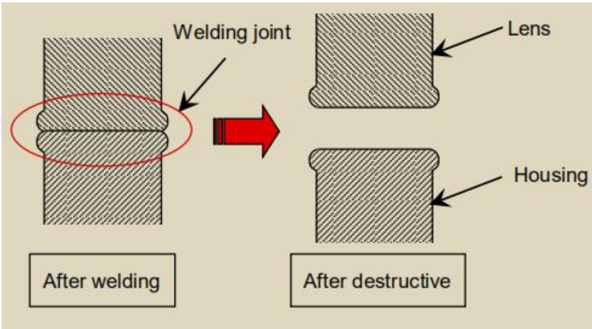


Figure. 7. Simulation of welding condition and after destruction of welding, this is for seeing the place of breaking

The two figures Figure 8 & Figure 9 show the surface of the joint after the separated, it's obviously that the surface is smooth and there isn't so much material left on each side.

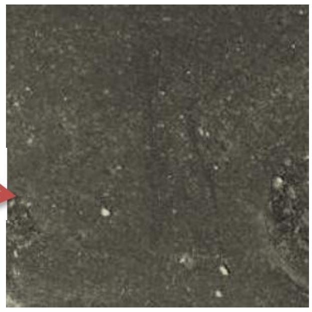


Figure. 8. Surface of the joint separated, the surface is mainly smooth

Figure. 9. Zoom of the joint part

Facts:

For the poor welding quality judgment point,

1. The lens and housing are separated from the welding joint.
2. From the macroscopic side : the surface of the welding joint is smooth.
3. From the microcosmic side : there are some graininess on the surface of the welding joint, but it is not so much and the surface is still smooth.
4. There is no housing material left over the lens welding line, and there is no lens material left over the housing welding line.

Welding height investigation result :

Bellow the figure 10 shows the qualified conjoint of the lens and housing. For the welding problem, the problem happened only on a certain area of the welding parts.

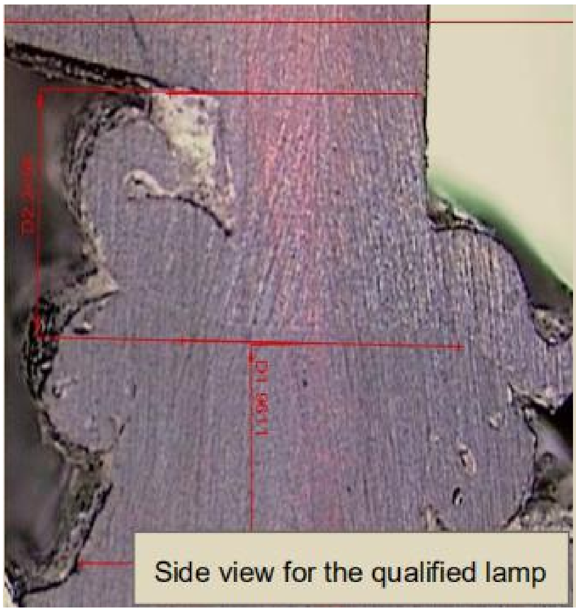


Figure. 10. The section view of the qualified light after welding, averagely welding and strongly connected.

In the figure 11, when the two parts are qualified welded the height and the housing are approximately the same height. And they weld on the middle line. D1=D2=2mm. However, the all unqualified parts don't match this standard. Figure shows the lens heights and housing heights in qualified condition and the 6 unqualified cases.

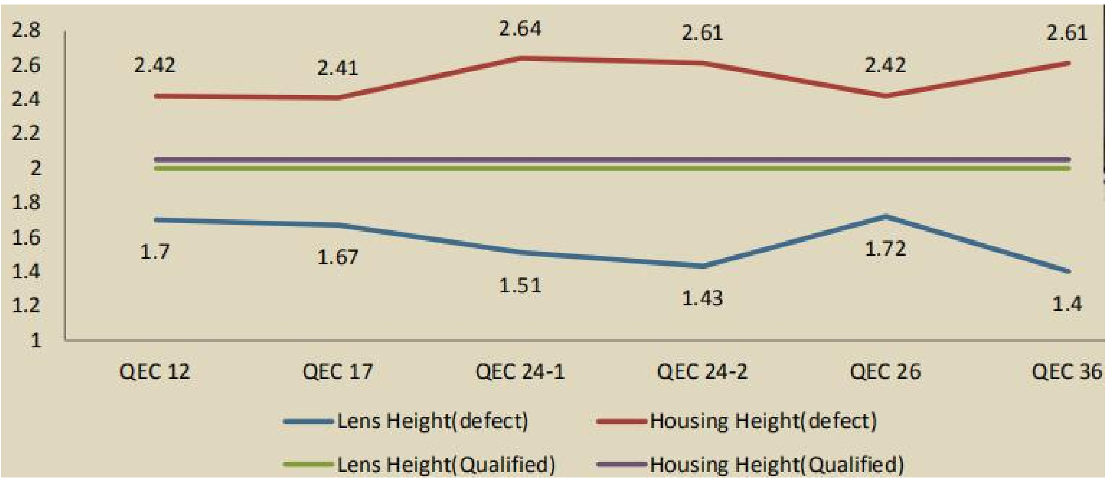


Figure. 11. Comparison of welding height statistics of each fault light and qualified welding height

Conclusion of measurement:

We summary the measurement result for the welding line height of the lens and housing, and to compare with the qualified light. For the defect light, the height of the lens after welding is lower than qualified. And the height of the housing after welding is higher than qualified.
The connected material is obviously little, so here in this area the water will come in. The strength between the welding joint are insufficient because of the badly welding condition.
Because these incidents are the same type of default, so only one example will be shown bellow in details, the analysis is based on all incidents given. QEC 17 is the example.

Issue	Part number	Part type	Batch/Shift	Customer complaint
QEC CNJ 2020 17	9817269580	Fender light RH	2019.8.5 day shift	Leakage defect

For this issue, customer complain that the leakage defect for this light.

When the supplier got the defect light, further visual inspection result: the welding quality of this light is very poor, the lens and housing was separated from the welding joint. Shown in figure 12 and figure 13.

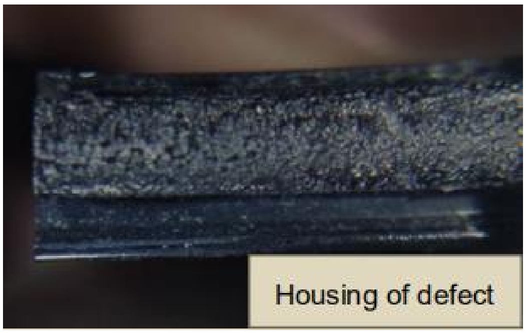


Figure. 12. The surface of defect housing of QEC 17 after destruction

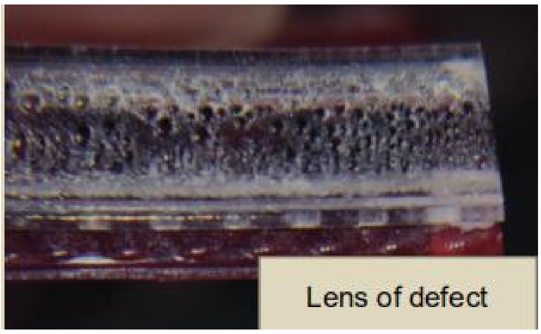


Figure. 13. The surface of defect lens of QEC 17 after destruction

The section view of both part are shown bellow in figure 14 and figure 15, the height of it is measured and compared.

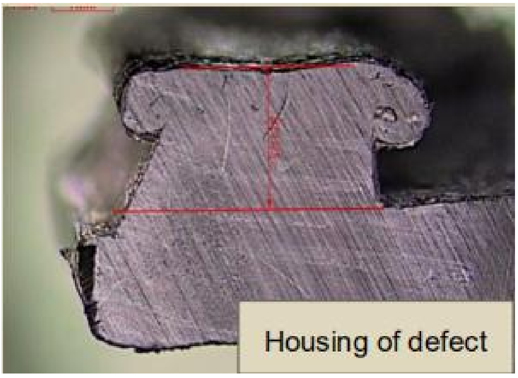


Figure. 14. The section view of defect light housing of Incident QEC 17

Figure. 15. The section view of defect light lens of Incident QEC 17

We measured the welding line height of the lens and housing for the defect light.
As a contrast, we also measured a qualified light, the measurement result are as bellow:

	defect	qualified
Lens	1.67mm	2.0mm
Housing	2.41mm	2.05mm

Fact:

1. The welding line height of the housing for the defect light is higher than the qualified light.
2. And the welding line height of the lens for the defect light is lower than the qualified light.

The welding joint of the defect light is so smooth, cannot meet the welding requirement in X supplier.

The objective for this part is to know the defect of the light, and try to know better the surface of the welding part. Then it won't be so difficult for doing the analysis.

The difficulty of the problem always comes from many unknown reasons,for each of them needed to be declared and detected to know if it is the real reason. So the investigation is essential for doing the analysis. Since there wasn't so many defect light sent for analysis, the analysis is limited. However the reason is mainly from the surface temperature of hot tooling, the soften height of the lens and housing, the welding height of lens and housing,material of the lens and the housing.

The analysis part will give more details for each possibility.

Materials/Tools/Methods/Results 1

Firstly let's review again of the welding process.

The hot tooling will firstly heat the lens which is on the top and the housing which is on the bottom. Then the hot tooling will be draw back. The lens and housing are both made of ABS/PC, so after heating, the material will be softened and they will be pressed by the pressure.

In the figure 16, the hot tooling will soften the welding line of lens, and the yellow side of the hot tooling will soften the welding line of housing.

During the welding process there will be some inner pressure created and annealing is necessary.After the light is welded and the light will be moved to a house for releasing the inner stress after welding.

The machine is shown bellow in figure 18, those bars around the hot tooling are used for adjusting the height and angle of lens, housing and hot tooling, the aim is to make sure the three parts are are equally in parallel so that during the process of welding, the soften part will be perfectly softened and both parts will be welded and connected perfectly.

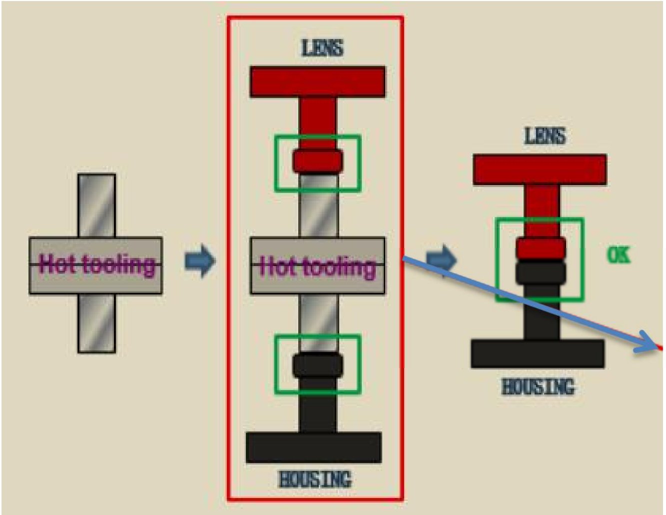


Figure. 16. Simulation of the process of welding

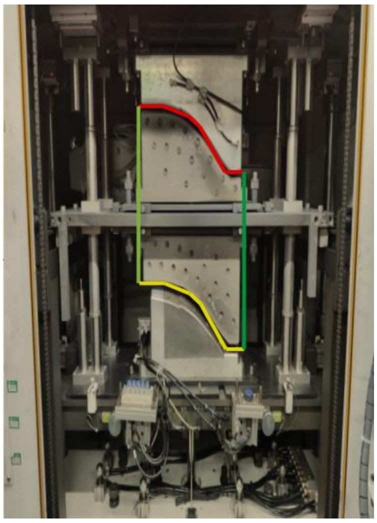


Figure. 18. Welding machine

Influence factor 1 - Surface temperature of the tooling

The surface temperature of the hot tooling will influence the welding effect, that is to say neither too hot nor too cold, non perfect surface temperature won't make a good welding condition. In each period the hot tooling temperature must be monitored and recorded, if the hot tooling is adjusted by the technicians. Bellow the figure 19 shows that the right side hot tooling temperature measurement results on 21 February.

If there are some adjustments, the technicians should note their changes. During the investigation, there is a suspicious phenomena, the temperature was tested by the machine but when the technician test its real temperature, the result is different. As is shown in the chart, the machine temperature is higher than the actual temperature. Figure 20 is the thermometer used to measure the temperature, and the figure 21 shows the diameter of the measurement tooling sensor with different size.

C84 Fender Lamp R_Hot tooling temperature measurement result													
Upper tooling								Lower tooling					
Date	Test point	1	2	3	4	5	6	Date	Test point	7	8	9	10	11	12
2.21	Standard (℃)	225.0	225.0	225.0	225.0	225.0	225.0	2.21	Standard (℃)	230.0	230.0	230.0	230.0	230.0	230.0
	Machine dislay (℃)	224.9	224.8	225.1	225.0	225.1	224.8		Machine dislay (℃)	230.2	230.1	230.0	229.9	230.1	230.2
	Test point	1	2	3	4	5	6		Test point	1	2	3	4	5	6
	Actual (℃)	209.6	204.1	207.3	214.5	214.8	212.9		Actual (℃)	202.7	220.0	222.4	205.9	211.8	218.8
Measurement: Li Wei			Check: Chunhua.Shi					Measurement: Li Wei			Check: Chunhua.Shi				

Figure. 19. Right-side up and low hot tooling temperature measurement result

Figure. 20. Thermometer

Figure. 21. the diameter of the measurement tooling sensor

Figure 22 shows the measurement position of the tooling.


Figure. 22. The measurement position

Supplier X sent the measurement result of the hot tooling last week, and the actual temperature is lower than the standard.

So why the temperature displayed on the machine is different with the actual temperature ?

Investigate result : Due to the diameter of the measurement tooling sensor joint is bigger than the width of the welding line. So the sensor joint cannot fully contact with the hot tooling, thus the measurement result is lower than actual temperature. So they measured the temperature again, after using the smaller diameter sensor joint, and the final measurement result shown OK.

Influence factor 2 - Soften height

For the hot tooling device, there is some structures that help adjustment during the process of softening. Bellow the figure 23 shows the main 3D position adjustment structure. The up ones and the lower ones will help modify the horizontal level of both holders of the lens and housing. All the adjustment might be mini since the height changes only by rolling the bolt on the bar. Even so, the height still can move little by little during the production.

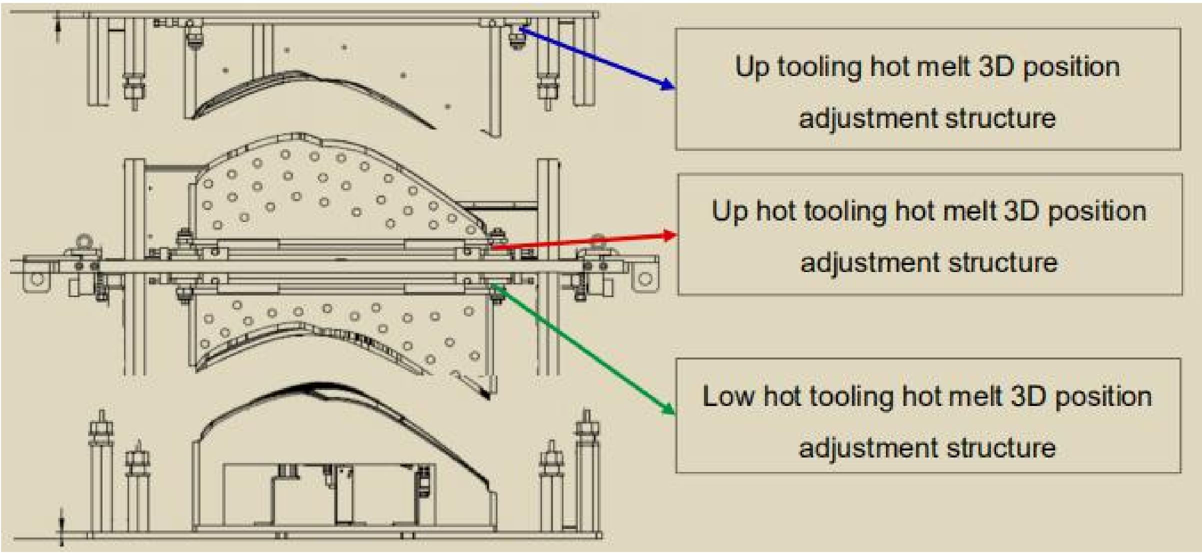


Figure. 23. The hot tooling 3D position adjustment structure

During the hot melt process, the technicians use these structure to adjust the soften height of the lens and housing. In order to get a same phenomenon like in the welding issue, the investigation were carried.

Testing fact: If we adjust these mandril, circle around of the welding line is nonuniform. The phenomenon is same with the defect lights.

Investigation results: The technicians of X supplier contacted with the process engineer. During the adjustment process, they will adjust these structure to optimize the measurement, but they haven't recorded these adjustment record.

Conclusion: no record for the 3D position adjustment structure. But the test results show the adjustment will influence the welding status.

As is shown in the figure 24, the normal situation for the soften process, welding process and after welding. All the parameters are perfectly matched in the normal situation, so for the welding joint they are perfectly connected.

The green line is the lens welding line and the blue line is the housing welding line. Every part of the line is heated en average. So the welding effect is qualified and the connection is strong enough with the qualified pressure. The figure shows well the process and the line is matched well.

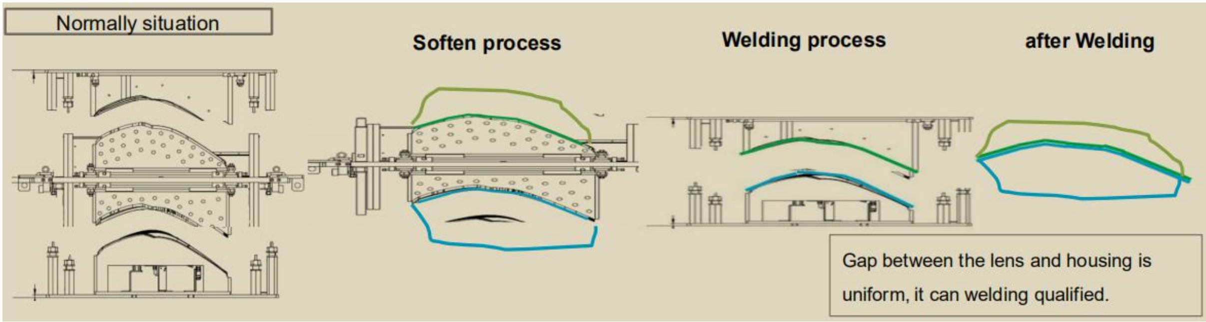


Figure. 24. The normal situation of soften process, welding process and after welding, the green and blue lines are connected perfectly. Blue part represents the housing and the green part represents the lens.

After the introduction of the normal situation. Let's check the situation that after a bad adjustment in the three process. Shown in figure 25.

In soften process if the red part is badly matched with the hot tooling and certain part is melted more some part is melted less. This can be caused by different reasons, for example during a long time of working, the height of the mandril will have some changes. If the technician didn't adjust it in time, there will be some defective lights product.

We can see the welding effect is bad. They are not perfectly matched. Some parts might have a gap, but these lights won't be able to delivered to PSA since they are picked out in the process of leakage checking.

Based on this point, the technician did the adjustment to see if this modification will repeat the situation. After they did the adjustment, they found the same defective light.

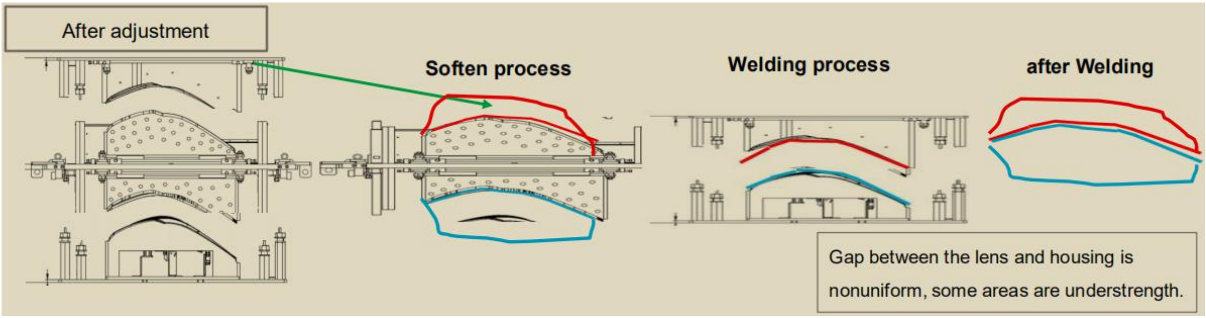


Figure. 25. The bad situation of soften process, welding process and after welding, the green and blue lines are connected badly with a gap between them

First conclusion:

After the height of z dimension was adjusted, plate of lens module deformed.

Influence factor 3 - Welding height

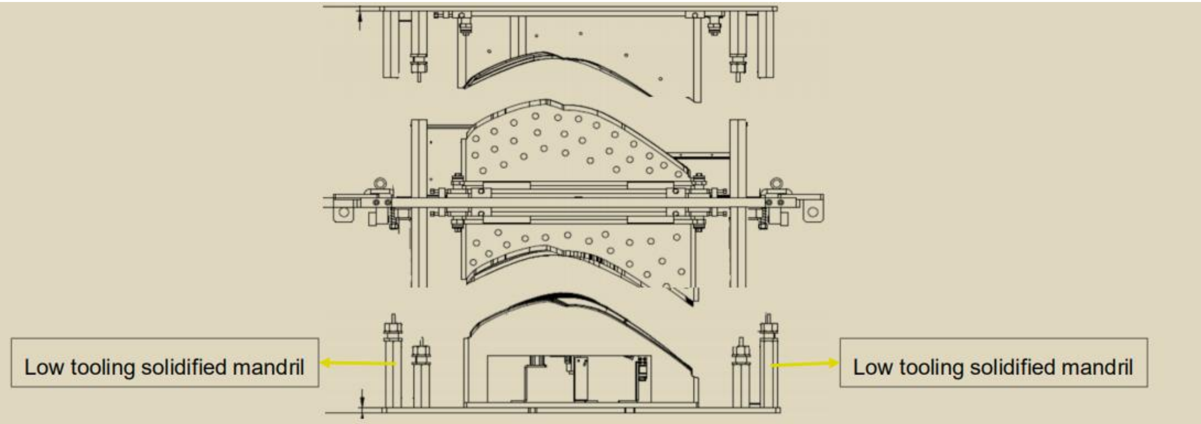


Figure. 26. Around the tooling are the mandril, they are used to adjust the welding height

Investigation results: During the welding process, use these structure shown in figure 26 to adjust the motion trail of the up tooling. If we adjust these mandril, circle around of the welding line is uniform. However, the phenomenon for the defect is different from these defect lights, their circle around of the welding line of the defect lights is nonuniform.

Incident QEC CNJ 2019 292(One incident happened in 2019, it was a leakage problem after sale) was caused by these mandril adjustment. And if the process engineer adjusted these mandril, they will record the detail information of adjustment. But during the investigation, there is no record of adjustment on those days.

First conclusion :

This is not the root cause for this issue since no record was found.

Factor 4 - Material

Material test results are OK. The degradation can happen after reprocessing of polymer. And this is the reason of the breaking of poly butadiene bonds. What's more, for certain additives, its effectiveness will be lost as a result of the reprocessing in ABS.[1]

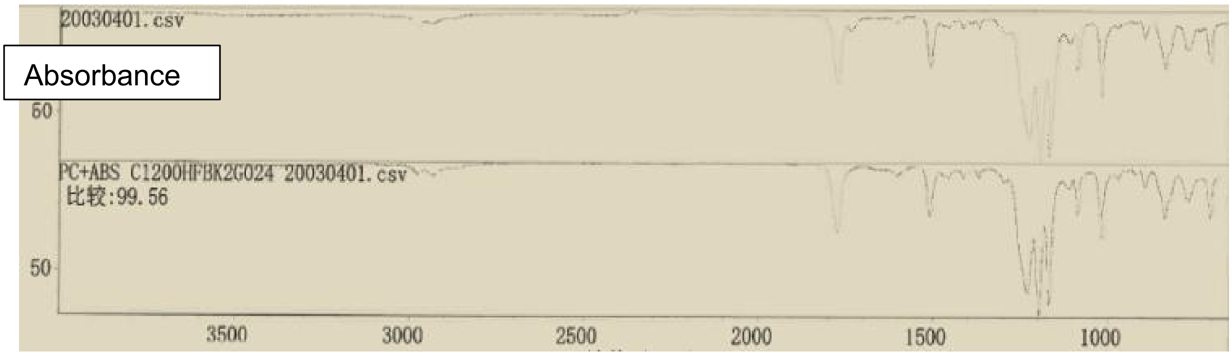


Figure. 27. The fault light material is compared with the results of the analysis of the qualified material.

Since the material used in the bad welding shared 99.56% similarity, we can conclude that the material used is qualified shown in figure 27.

Conclusion : Cutting some material from the lens and housing of defect lights to do the material test. And the test result shows the material are qualified.

Analysis/Discussions

There are four main factors for this issue, the last part only provided three factors investigation. The rest one is the material. We will give a short discussion about it in this part since it's not the final reason.

Factor 1:surface temperature of the hot tooling

For the first factor, the surface temperature of the hot tooling, it is tested that it have the possibility to influence the welding condition. Since the temperature of hot tooling can directly influence the softness of the material and it will influence the welding in the end. So this factor need to be pay more attention and avoid.

They cannot find the record for the actual temperature of hot tooling in defect shift, and X needs to optimize the control plan for the temperature management.

The technical conclusion of this factor is decided unsure if it is this factor caused this welding problem. Because of the careless omission of the workers in production line. The technician of X couldn't justify if this factor is the final reason of this issue.

Discussion 1: Since the temperature of hot tooling is one possible reason, plan of action for avoiding the issue is needed. Because from the point of view of the interests of suppliers, the recording of each adjustment can effectively help to analyze some adverse causes, in the production process some adjustments or certain unstable data, if fully recorded, can quickly help to analyze the real cause and effectively eliminate other causes.

Plan of action 1: The actual temperature is measured every shift before production starts and all records will be uploaded to the company's cloud.

Factor 2:soften height

The second possible influence factor is the the soften height of the lens & housing. If the height of either part is changed the welding will be unqualified. During the process of analysis, the height(3D structure) of both parts are changed to verify if we can repeat the same issue.

The result is yes. The process of how does soften height influenced the welding condition is that once the soften height is changed, then the soften level won't be the same for the welding line, in the same time the less soften part will have a less possibility to weld well or weld strongly.

So **the conclusion(2)** of it is one possible reason, but process engineer haven't recorded the adjustment process.

Analysis: There is always the detection measure of the leakage of water and air, why they didn't find the bad lights. It is because the badly welding light will have possibility to ensure the test standards. However, in this situation, these light might not be able to make sure that after a few months of delivery and vibration still fit the standard (For this, it is just a possibility guessed, it cannot be used as a real reason since it is not verified and proved.). So there are many lights were found after the Trigo started the sorting in the storage. We can't say it is this reason that caused it, but this is still can be a possibility of bad welding problem but without leakage of water.

Then after the hot tooling is draw back, the red line which is the lens welding circle cannot matched well with the blue line which is the housing line. That is to say during the soften process, the lower area is soften more and the higher part is soften less. In a easier condition, supposing the housing welding circle is soften perfectly and averagely, when they weld, the more soften part will be connected easily and the less soften part won't be able to connected fully of its materials. The more soften area is too soft to hold the material, so it is pushed more and the material is squeezed out. And the less soften part is too hard to weld well, so this area is also poor adhesion. So in both areas the welding strength is weak.

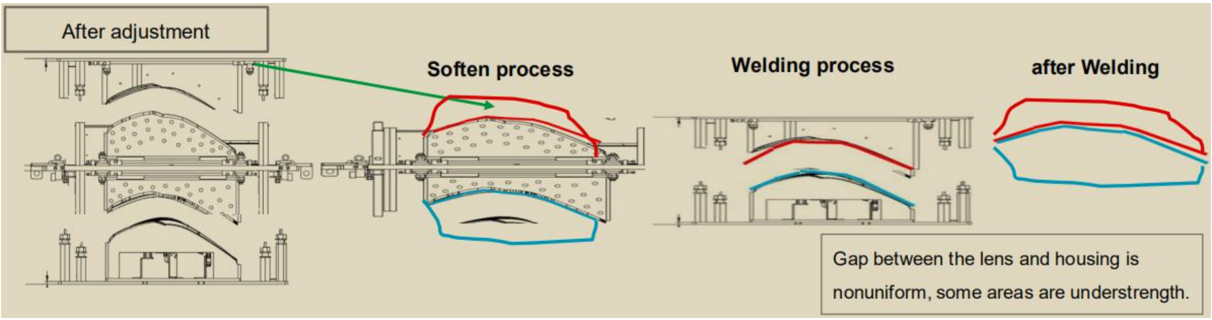


Figure. 25. The bad situation of soften process, welding process and after welding, the green and blue lines are connected badly with a gap between them

Discussions 2:

This part is introduced in detail above. This factor is considered a very likely cause, both personally and from a supplier's point of view. So in this case, it is very necessary to have an action plan to avoid this problem. Such an action plan should be considered in terms of the level of technical adjustment and monitoring, one from the root causes to avoid, the other from a monitoring point of view to avoid incidental events.

Even though the leakage checking process can help eliminate some obvious defective lights. There are still a possibility of badly welding light come to the production line but they don't influence the appearance and strength of the light.

From the past experience, the welding joint might be pushed out some materials if the horizontal level is not perfectly the same. Then the welding effect will be bad and the size dimension won’t be under control. In this situation it will have a possibility to overpass its own tolerance.
Like what has been talked above, the light will be looked like the same from the front. But the side of the light, for example, the welding joint part will be not perfectly welded. That is to say some parts are not soften well some parts can be softened too much or less. Both situation won’t be a good thing for the production. But after the investigation and tested by the supplier X, they said that this situation won’t cause the welding leakage problems and the out appearance of lens is not influenced. So this is not the root cause of the situation.
Plan of action 2: Training the process engineer, record the adjustment of 3D z position adjustment structure. After the z position adjustment each time, do the press test to confirm the feat status.

Factor 3:welding height

In the analysis of this possible factor, although welding problems have also been found, the results of the experiments do not match this welding problem. So it can be concluded that this is not the root cause of the accident. Another point that can help rule out this is that the mechanic responsible for this records every adjustment, so you only need to look at the time of the fault light for a period of time to determine whether it is the cause. It turns out that this is not the case.
Technical conclusion : No adjustment record have been found, and the phenomenon of the defect lights are not caused by the solidified mandril adjustment.

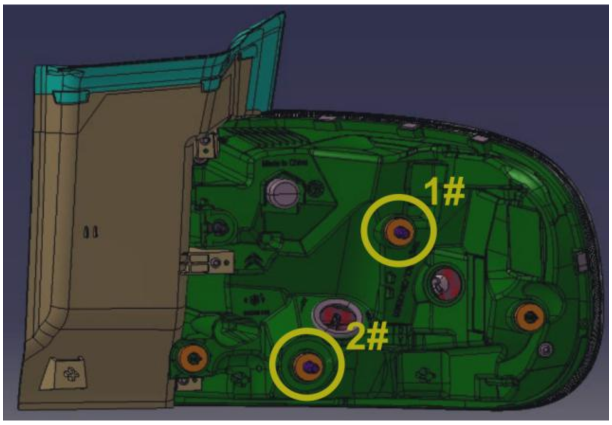
2. Cracking problem

Introduction 2

Incidents in PSA Rennes

N. Incidents	Error date	light side	Description	Batch
QEC CNJ 2020 38	2020.02.20	Rh	Leakage defect caused by the cracking at the bolt hole	2019.9.21
QAN CNJ 2020 50	2020.03.02	Lh		2020.1.5
QAN CNJ 2020 63	2020.05.26	Lh		2020.1.3
	2020.06.02	Lh		2020.1.8

Defect description:
1. It is after the PSA Rennes firstly found this issue when they did the leakage test, then the supplier X began to analyse the problem.
2. After checking the defect lights, the bolt hole cracked and caused the leakage defect.
3. There are 2 bolt holes on the housing, and the cracking position for these defect lights are as below figure 28:



System number	Cracking position
QEC CNJ 2020 38	1# & 2#
QAN CNJ 2020 50	1#
QAN CNJ 2020 63 1#	1#
QAN CNJ 2020 63 2#	1# & 2#

Figure. 28. Bolt position

The following are all the photos of the defect lights, shown in figure 29:

Figure. 29. Cracking situation

The water was entered from the bolt hole.

The challenge of this problem is that it is not easy to analyse, because the defect light was firstly found in the PSA Rennes, so there is a time difference between its production and its cracking. Under this condition, it isn't easy to do the tracking of the cause of the problem. Since recently the bad light were all lift side, so it is decided to do the sorting in case of no more incident happens.

Methods/Analysis/Technical Conclusion

Different from the first issue, this cracking issue can be caused by many factors. The external non predicted force, the stress or the strength can cause the cracking somehow. So each factor should be checked and verified in order to find the real reason, from the experience, it is really a tough job to analyse for deciding the final cause.

The analysis and technical conclusion will be written together and the discussion will be given after all the analysis provided.

Factor 1. Shocked by external force

For this factor, we need to analyze it because during sea transportation, repackaging or installation, there may be external force impact resulting in the bolt hole cracking. It is easy to analysis because we only need to have a complete appearance inspection for judging. For the appearance front and back sides, check the figure 30, no scratch was found on all the lights returned.

Figure. 30. There is no scratch on the appearance of these four lights

Appearance inspection :

No obvious bumps or scratches were found in the appearance of the problem light. Figure. 30.

Conclusion: No external force has ever hit the problem light, and this factor can be ruled out.

Factor 2: Abnormal force during assembly

1. Bolt assembly status on housing

(1) In the supplier factory, they use the balance bracket fixture to assemble the bolt to the housing, which can avoid the abnormal assembly angle.

(2) The regulation demand that the workers must record the torsion of screwing every 3 days and the torsion records of defect batches are qualified. (X company requirement: special line measure the torsion every 3 days, if not, need to measure it every day)

Figure. 31. Balance bracket

Figure. 32. The torsion record

2. Bolt assembly status on the car body

Test: Stick the pads on the cubing gauge to simulate the uneven stress in car body assembly, then use the torque force of 2Nm to lock. In the end they found no crack after 1h and 20h. figure. 33.

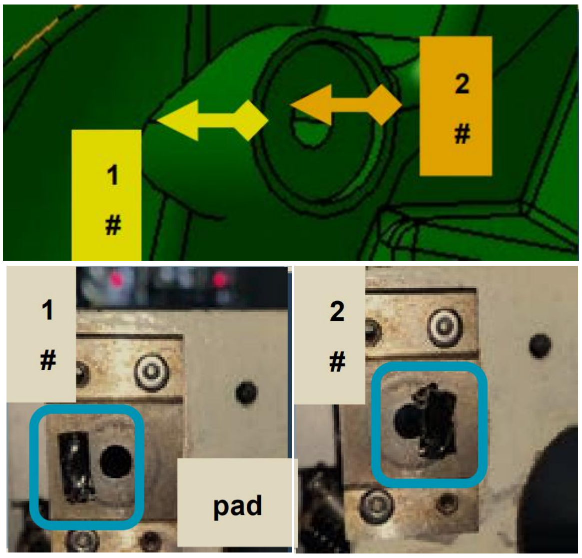


Figure. 33. Uneven force simulation test

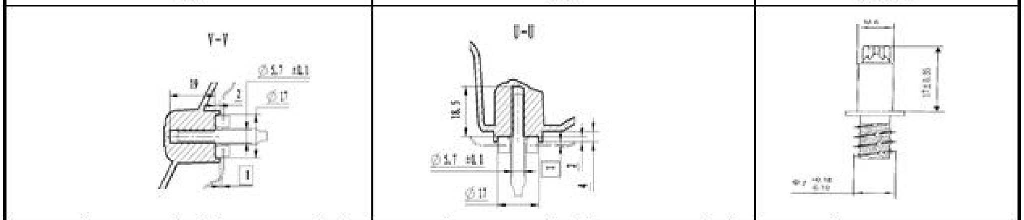
Conclusion: Because in the bolt assembly process on housing and the process of assembly on the car body are all considered to avoid the badly assemblage, so after checking this can be eliminated from the possibility. **No abnormal force during assembly.**

Factor 3: Dimensions issues investigation

Since the dimension of the bolt hole can influence the inner stress of the light. When there was still inner stress near the bolt hole after its annealing, then if the bolt got some more stress outside for instance from the bolt, it will crack more easily. So the measurement of the bolt hole is obligatory.

Measurement: Measure the two holes' dimensions of returned lights and the lights in X stock, for all dimension measured, shown in figure 34.

C84 Fender Lamp measurement



1#					2#					screw	
	5.7±0.1(mm)		19±0.2(mm)			5.7±0.1(mm)		18.5±0.2(mm)		Number	7(-0.1/+0.18)(mm)
Number	L	R	L	R	Number	L	R	L	R		
1	5.66	5.69	19.09	19.04	1	5.64	5.68	18.40	18.40	1	6.96
2	5.67	5.65	19.12	19.10	2	5.65	5.64	18.31	18.33	2	6.96
3	5.60	5.64	19.03	19.05	3	5.63	5.62	18.40	18.31	3	6.99
4	5.64	5.65	19.10	19.05	4	5.68	5.67	18.37	18.31	4	7.00
5	5.68	5.63	19.03	19.13	5	5.64	5.65	18.31	18.34	5	7.00
6	5.62	5.64	19.13	19.15	6	5.64	5.66	18.33	18.32	6	6.99
7	5.67	5.62	19.02	19.07	7	5.63	5.67	18.34	18.31	7	6.97
8	5.69	5.67	19.09	19.11	8	5.66	5.67	18.39	18.40	8	6.98
9	5.67	5.64	19.13	19.02	9	5.66	5.67	18.40	18.39	9	6.98

Figure. 34. Dimension measurement report

Result & Conclusion: The measurement result of the size shows that the error of each size is within the allowable tolerance range and meets the size requirements, so the size is qualified, and the influence of the size factor on this problem can be excluded.

Factor 4: Environment simulation test

Since the environment can also influence the stress, so the test for the environment factor should be verified. For the environment factor there are two possibilities, chemical reagents and the alternating temperature. For chemical reagents, there are some chemical products used during the production and the assemblage, that might cause the cracking. And after the production of lights, they will be transported to many different places with different humidity and temperature.
Based on this two points, the relative experiments should be carried out.

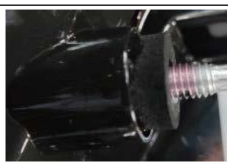
Chemical reagents test: Windshield washer fluid / Automobile brake fluid / Alcohol / tooling cleaner.

Test method:

① Apply each reagent to different housings then lock the loading bolt and cubing gauge, and place at 20 ℃ or 50℃ for 30 minutes, and then lock the bolt and the cubing gauge.

② Apply the reagent after the screwing process, place at 20 ℃ or 50℃ for 30 minutes, and then assembly the housing to the cubing gauge.

Results: below the table shows the test result.

Test		Windshield washer fluid	Automobile brake fluid	Alcohol	Tooling cleaner
Picture					
Appearance		No change	No change	No change	Be corroded
①	20℃	No cracking	No cracking	No cracking	Cracking
	50℃	No cracking	No cracking	No cracking	Cracking
②	20℃	No cracking	No cracking	No cracking	Cracking
	50℃	No cracking	No cracking	No cracking	Cracking

Chemical reagents test results

Conclusion: Special chemical reagent will reproduce cracking issue, but reagents in X process will not cause cracking like returned lights.

Temperature alternating test(8 Cycles)

Method: Put the light from a 23℃/80% ambient humidity to the environment of 80℃, for 4 hours and then put it in the -40℃ condition for 4 hours. Shown in figure 36. Then lock the bolt then check the condition of the bolt hole.

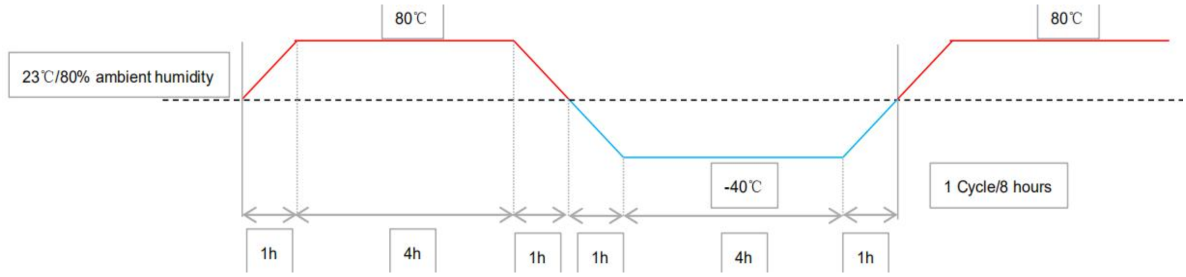


Figure. 36. Temperature alternating test(8 Cycles)

	L-1#	L-2#	R-1#	R-2#	Result
3rd cycle					OK
5th cycle					OK
8th cycle					OK

Result: After some cycles of repeating the experiments, there is no cracking issue happened.
So after simulation of the real environment changing its condition, we can get a certain conclusion as following.
Conclusion: The stress of the locking bolts do not cause cracking.

Factor 5: Oil on the bolt

If there is oil on the bolt, after install the bolt, there might be inner stress. So they put the bolt into the water to see if there is oil exist.
Method & result:X rechecked the bolts on the defect lights and X's stock, and there is no oil on the bolt.
Conclusion: There was no oil reagent on the bolt.

After the stress analysis, it is the strength analysis, it includes Housing design structure analysis, material test, chemical reagent simulate test, housing injection process investigation.

Factor 6: Housing design structure analysis

There are 2 parts for verifying the structure factor.

1.The cracking position is not at weld line.

If the cracking position is the weakest part then the structure should be improved. So it is better to check if the cracking part is from the weld line.

Method:

Checking the cracking position to see if it is the weld line. In the figure 37 the green area is where the weld line lies and the most serious cracking part is marked by the red line.

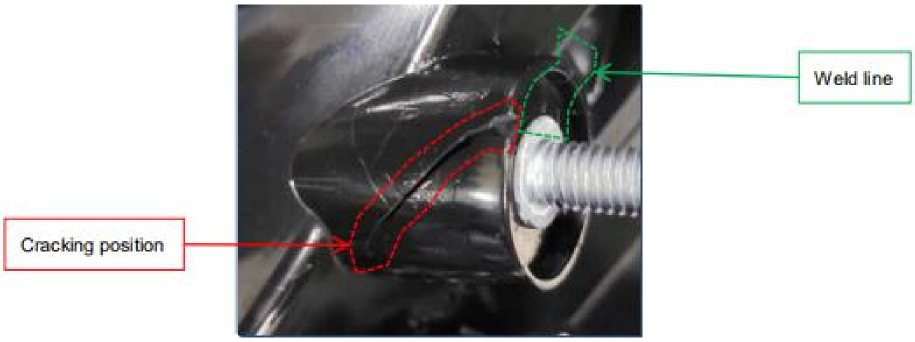


Figure.37. Cracking position and weld line position

Result:

The cracking position and the weld line are not in the same place.

2.CAE static structural analysis(by supplier)

Simulation conditions:

Simulate the constraint conditions of the whole light, and increase the load of 4N.m (double stress) at the bolt hole position. This is to verify if the structure is qualified under a certain torque. Under the figure 38 shows the result of the static structure analysis.

Test result:

The stress is within the standard, the housing structure is OK.

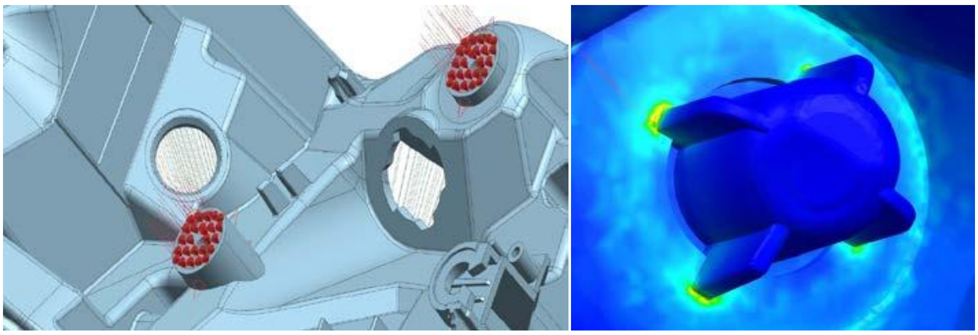


Figure. 38.Simulation conditions

Conclusion:

There is no stress concentration around the bolt hole. And the structure has no problem in theory.

Factor 7: Material test

1. Compare material between returned lights and qualified lights

Do the material test (Vicat test(figure 39) and Infrared spectrum test (figure 40)) for the defect housing and qualified housing, and compare the test result between them.

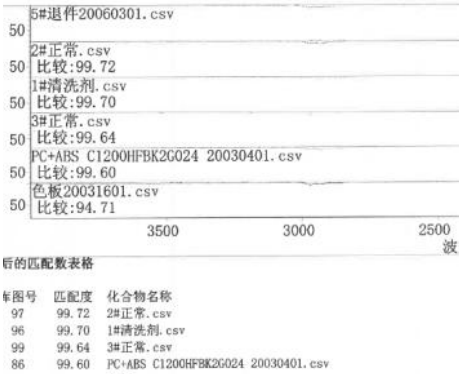


Figure. 39. Vicat test result

Figure. 40. Infrared spectrum test result

Result & conclusion:

The test results are OK shown in figure 41. The material for the defect light is the same like the qualified light, so the material is not the reason.

2. Measure the molecular weight between the cracking and not cracking positions of the return light to confirm the material stress.

		Mw	Mn	D
561244	NG-1	42020	16174	2.60
561244	NG-2	41872	16150	2.59
561244	NG-3	41565	15747	2.64
561245	OK	41665	15878	2.62

Figure. 41. Molecular weight of NG and OK

Conclusion:

(1) The material of the defect lights are qualified.

(2) The strength of the material isn't degraded.

Factor 8: Chemical reagent simulate test

One of the most possible causes is the chemical products. It can damage the surface of the light of damage the material then the strength of the bolt hole will be weaker. So all the chemical products used or not used during the injection process should be tested and verified to know the influence.

The residual chemical reagent simulation test:

Chemical reagents used during injection: Tooling cleaner(Supplier)/ Tooling cleaner/ Release agent/ Anti rusting agent.

Test method:

Apply each reagent to tooling then start production in which the reagent will be used, till the reagents are all exhausted. Then check the appearance of the bolt hole and lock the loading bolt and cubing gauge.

There are four molds prepared for doing the test. In the beginning each mold is put different amount of the reagent. In the beginning install the gauge with a torque of 2N.m(Standard requirement in assemblage) and 4N.m. Then install the gauge for each after different time with the torque of 2 N.m. The time after production differs from 6 hours, 24 hours and 7/14/21 days.

	1st mold	2nd mold	3rd mold	4th mold
Tooling cleaner (Supplier)				
Tooling cleaner				
Release agent				
Anti-rusting agent				
Bolt HSG (2.59N.m)	No cracking	No cracking	No cracking	No cracking
Install the gauge (2N.m)	No cracking	No cracking	No cracking	No cracking
Install the gauge (4N.m)	No cracking	No cracking	No cracking	No cracking
Install the gauge (2N.m) (After 6 hours)	No cracking	No cracking	No cracking	No cracking
Install the gauge (2N.m) (After 24 hours)	No cracking	No cracking	No cracking	No cracking
Install the gauge (2N.m) (After7/14/21days)	No cracking	No cracking	No cracking	No cracking

Result:

All the four products used during the process of injection didn't cause the cracking.

Conclusion:

Chemical reagents used during injection process can not reproduce this issue.

Factor 9: Housing injection process investigation

1.Check injection tooling maintenance record

=> The bolt hole position of the tooling has not been repaired.

2.Check the injection process

(1) Injection process records

=>All records about materials, temperature, inject pressure and inject velocity are qualified shown in figure 42 and 43.

Figure. 42. No repaired record Figure. 43. All records are normal

Verification of injection process with short injection parts

(2)If the velocity difference between left and right parts is out of qualified range, the fast formed part materials may degrade under pressure and result in insufficient strength.

The figure 44 show the process that when inject the left and the right part together, and check if they will finish their injection the same time. Picture 1 to 5 shows the different period of injection. If the left and right parts are not formed in the same time(very near), then the first formed part will continue be heated and pressed under a high temperature and high pressure. Which will cause the material degrade or damaged. However if they form almost in the same time, it means that the velocity of injection on both sides are OK.

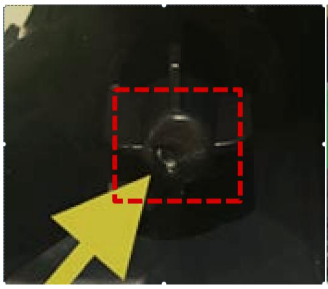
Figure. 44. Flow velocity between left and right

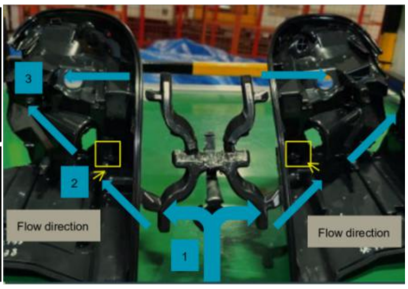
Result:

Through the verification of short injection parts, the velocity difference between left and right parts is within a qualified range.

3.Check the tooling structure

(1) Confirm the status of the bolt hole column with short injection parts.





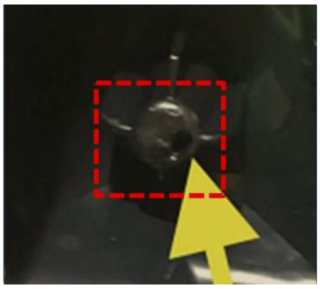


Figure. 45. R:bolt column not formed Figure.Inlet gate Figure.46. R:bolt column not formed

From the process of injection, the bolt column hasn't formed in the position 2 while the position 3 has already formed. This means that there is some problems during the injection process. The problem is that the injection material isn't pure, that is to say some gas might be trapped inside the material. And since the position 2 is higher that other part so the gas is pushed in the end of the position 2. And finally under the high pressure, the gas caused the material couldn't form well.

Conclusion: When the molten material flows to position 3, the bolt hole at position 2 is still not formed, we can judge that there is gas trapped defect in the injection tooling structure.

(2) Dismount the injection tooling

The surface of bolt hole tooling is scorched due to gas trapped shown in figure 47, because the gas will increase their temperature with the increasing of pressure and decreasing of volume. So it’s better to add a gas exhaust structure design at the bolt hole. Figure 48 shows normal condition without scorching.

Figure. 47.The grey part is sealed

Figure.48. Normal: no scorching

(3) Influence of gas trapped

1) The arrows shows the molten material flow direction, The grey part is gas. Figure. 49.

2) When the molten material flows to the bolt hole, the gas will be compressed and the column can’t be formed. Figure. 50.

3) Under the action of pressure, air is mixed in the molten plastic. Finally after high temperature damaged the plastic, resulting in insufficient strength.

In the beginning of injection, the temperature inside of tooling is not stable and cause material flow unsteadily , the trapped gas will affect PC/ABS material combining effect. Then reduce the strength of bolt hole.

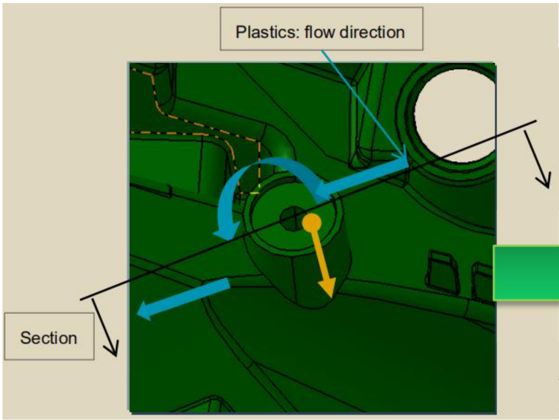


Figure. 49.molten material flow direction

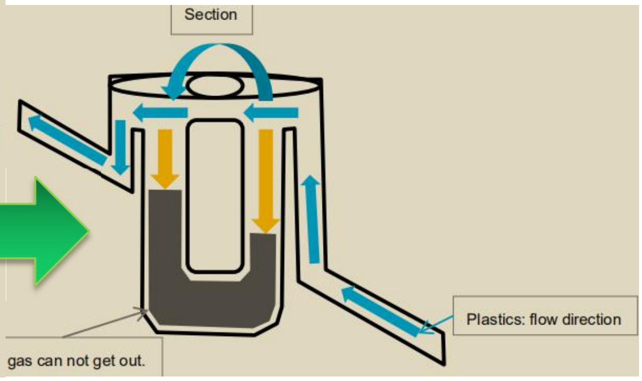


Figure. 50. Flow direction in the bolt hole

(4) Confirmation of defect parts

1) The red part is the crack part, and the surface is smooth, which indicates that the quality of material bonding is insufficient.

2) The green part is the not cracking part, the plastic turns white after being cracked manually with stress.Figure. 51.

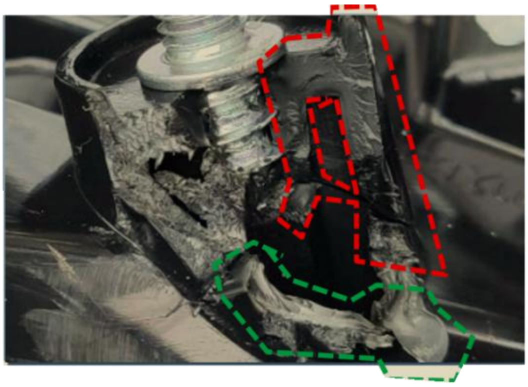


Figure. 51. Compare of cracking and after stress cracking

(5) Reproduce test

In order to verify the defect is caused by this reason, we need to do the reproduction test.

1) Use the same type of light colored material for the reproduction test, the samples were not scorched, and no cracking after locking for a week. Figure. 52.&Figure. 53.

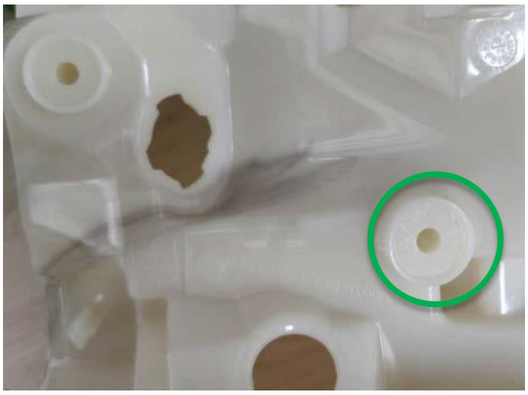


Figure. 52. No scorching

Figure. 53. No cracking

2) Track a batch and 100% lock verification and retest after a few days.

Date	13/06/2020	14/06/2020	19/06/2020	25/06/2020	01/07/2020
Inspection quantity(pieces)	370	20	20	20	50
Result	No cracking	No cracking	No cracking	No cracking	No cracking

Conclusion:

X found the injection tooling structure have gas trapped defect, which will affect the housing strength, but the defect cannot be reproduced.

Discussion:

Because some molds are scorched, so firstly we need to clean the scorching surface. On the mold we also need to add the exhaust structure like shown in figure. For the exhaust structure, it is very small hole with the diameter of 0.1mm. Figure.54. So only the gas will get out if there is gas mixed in the material but the plastic won't get out of it. And after 1st July, the product with the modification have been carried out, until now there isn't new cracking issue found after full inspection in X factory.

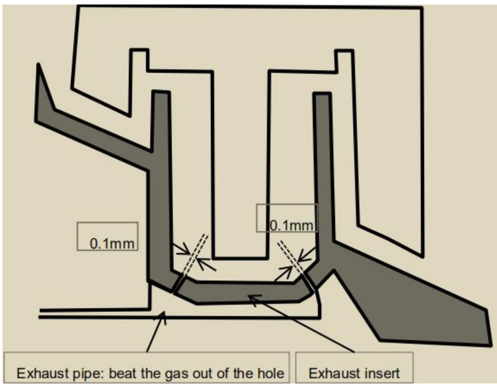


Figure.54. After adding holes on the mold

The bolt hole structural can be optimized, for example add standard rounded corners to prevent uneven injection of materials and add countersunk holes to ensure the verticality of bolts and bolt holes.Figure.56.

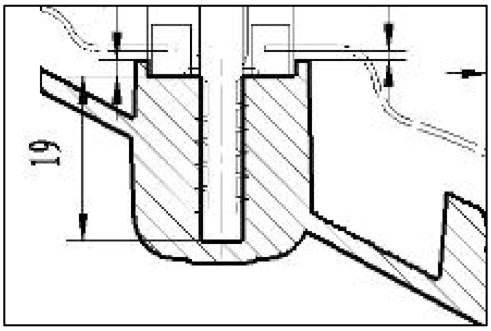


Figure. 55. before change

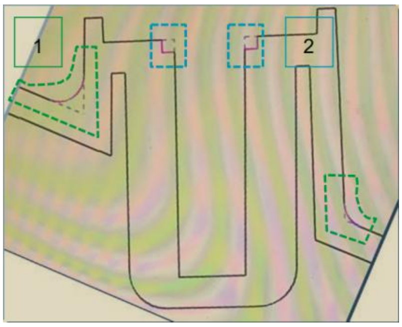


Figure. 56. After change

After all the analysis for each factor, for the supplier, they didn't find the real reason though they did some important tests. For all the factors verified it is sure they are not the final reasons. But for the two factors, environment chemical reagent and housing injection process, they can only say that it is a possibility. There isn't the solid truth to defend the two factors.

The supplier got less lights for doing the analysis, they didn't have enough lights to verify the situation. However, as a resident in PSA, I have checked many defective lights after sorted by Trigo. There are about 25 defect lights found cracking. It is sure that it was the bad injection that caused this issue. Because I checked each light cracked in the factory. For each light, the most serious cracking part is the same. Figure. 57. If the start cracking position is the most cracking area, then it is sure that they all caused by one same reason. This reason is injection process defect, either because when they start a day after stopped using their machines, the material might mixed with air in the beginning, or the material wasn't cool down well or concreted well. In this condition the material will be fragile so the cracking can happen with some vibration or torsion.

Figure. 57. Cracking situation after dismount the bolt

Although no very strong final cause has been identified, some of the factors that may have contributed to the phenomenon have been examined accordingly, and the current tracking results show that the improvement did not occur.

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