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CFD Application to Eliminate Delamination Defects in Flange Products

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ABSTRACT

Delamination defects in the breather pipe of flange products produced through the injection molding process are a critical issue that affects product performance. The objective of this study is to reduce the detected delamination rate by 3.77% from a total of 2173 production units, with a maximum allowable limit of 0.5%. The method applied includes identifying the cause of delamination through analysis by collecting defect data, analyzing through the CFD (Computation fluid dynamic) method, and observing mold conditions. The proposed solution focuses on improving the slider motion mechanism of the mold and adding a gas vent with a vacuum system. Test results showed that these improvements succeeded in reducing the delamination rate to 0%. Further evaluation through X-ray analysis and microscopic checking confirmed no significant voids in the breather pipe and the integrity between material layers. The conclusion of this study confirms that foreign material, in the form of plastic debris and gas burn deposit injected due to slider mechanism failure and lack of gas vent, is the main factor causing delamination. This study is expected to provide comprehensive guidance for the industry in addressing similar issues in the future.

Introduction

Injection molding or plastic injection is the most commonly used method of the product manufacturing process in producing plastic products by molding. Many plastic products are produced from this method (Myers, Mulyana, Castro, & Hoffman, 2023). From simple products such as plastic cups, mobile phone casings, and children's toys to complex products such as dashboards, fuel pump flanges, four-wheeled modules such as (cars) and two-wheelers (motorcycles), and aircraft components. The results of the injection molding process are almost always used in daily activities (Yilmaz, Yang, & Turng, 2019). The machine used for the injection molding process is called a plastic injection machine. The injection molding process requires a plastic mold. Mold is a tool used to shape a product according to the design we want (shape and dimensions). Mold is formed from two main parts, namely cavity and core (Wang, Wang, & Chen, 2022).

The two are an inseparable unit, because the combination of the core and cavity will form the components that form the product (Iswanto, Rambe, Jabbar, & Ginting, 2013). The number of product formers in a plastic injection mold is called the number of cavities. A mold that has 2 cavities means that the mold can produce 2 products in each shot (every 1 process cycle) (Badarisman, Hamid, Ideris, Bakar, & Jalar, 2022).

Flange is an important component of FPM (Fuel pump module) or fuel pump module on 4-wheeled vehicles which is produced through a plastic injection process using a hot runner system mold and a 220t tonnage vertical injection engine (Ghorpade & Shinde, 2022). The flange serves as a link between the inside and outside of the fuel tank. In the initial stage of flange production, delamination defects were found in the breather pipe that did not appear continuously, but the percentage of defects that occurred was 3.77% of the total production of 2173 units, this was not by the target that had been set, which was a maximum of 0.5% (Permana, Topan, & Anwar, 2021). Research is needed to analyze the causes of delamination defects that do not appear continuously and comprehensive corrective measures to reduce and even eliminate the problem of delamination production defects in the breather pipe part of Flange products (Prasad, 2021).

Table 1 Flange Production Data

Day	1	2	3	4	5	6	Total
Production (units)	444	472	470	183	159	445	2173
Defects (units)	15	14	10	3	17	23	82
Defects (%)	3.38	2.97	2.13	1.64	10.69	5.17	3.77

According to Prasad in Rex journal volume 9, Issue-5 (2021:14) states that delamination is a mold defect that occurs when a thin layer on the surface of a printed part quickly separates or peels off from its base material, in other words as a peeling surface layer defect. The most common causative factor that results in delamination is the penetration of *foreign materials* into plastic materials. When two materials cannot bond to each other well then there will be separation of layers (Katkhede, Raut, & Labade, 2017).

According to A.H Badarisman, K, Abdul Hamid, H.Ideris, M.Abu Bakar, A.Jafar (2022: 6) stated that *molding temperature* is the highest effect of the delamination problem on SOT packages.

Method

Identify the problem

The problem of delamination defects that occur in the breather pipe part of flange products is researched how it can occur continuously, what are the main causes and what kind of improvement steps are appropriate to overcome the delamination problem.

Figure 1
Delamination defects in breather pipe flange products

Literature Studies and Research Reviews

Literature studies and previous research reviews were conducted to build a strong knowledge base and compare different research methods that have been used to address similar problems and determine the most effective methods. By doing this, it is hoped that the limitations of previous research can be understood so that they can be avoided or improved in new research.

Data collection

Production data is collected to obtain facts about the number and percentage of delamination defects from the number of flange units that have been produced. Specifications of materials, machines, molds, and test equipment to be used are also collected for study.

Data processing

Material

Flange products use POM (polyoxymethylene) material from polyplastic manufacturers with duration type M90-44. The general characteristics of this material are shown in Table 2.

Table 2
General Characteristics of POM Duracon M90-44

Item	Unit	Test Method	Standard M90-44 Standard
Color			CF2001/CD3068
ISO(JIS)quality-of-the-material display:		ISO11469 (JIS K6999)	>POM<
Density	g/cm^3	ISO 1183	1.41
Water absorption (23°C,24hrs,1mmt)	%	ISO 62	0.5
MFR (190℃, 2160g)	g/10min	ISO 1133	9
MVR (190℃, 2.16kg)	$cm^3/10min$	ISO 1133	8
Tensile strength	MPa	ISO 527-1,2	62
Strain at break	%	ISO 527-1,2	35*1
Tensile modulus	MPa	ISO 527-1,2	2,700
Flexural strength	MPa	ISO 178	87
Flexural modulus	MPa	ISO 178	2,500
Charpy notched impact strength (23℃)	kJ/m^2	ISO 179/1eA	6.0
Temperature of deflection under load (1.8MPa)	℃	ISO 75-1,2	95
Coefficient of linear thermal expansion (23 - 55℃、 Flow direction)	$x10^{-5}$/℃	Our standard	12

Injection Machine and Setting Parameters

The injection machine used is JSW JT 220 RAD 410V series with a screw diameter of 46mm, a maximum injection pressure of 239 Mpa, and an injection volume of 207 cm^3 with setting parameters shown in table 3.

Table 3
Process setting parameters

Parameter setting	Value
Stroke	116.5 mm
Injection Speed	10-40-15-40 mm/s
Cooling time	13.0 s
Hold Pressure [waktu]	55 Mpa [20 s]
RPM	110 min^{-1}
Back Pressure	8.0 Mpa
Barrel Temperature	190-195-190-180°C
Mold Tempearature	45 °C

CFD Analysis

Computational Fluid Dynamics (CFD) allows visualization of material flow in the mold, helps identify areas with poor or uneven flow, and looks at temperature and pressure distributions as well as the uniformity conditions of the frozen layer to identify delamination in the breather pipe part of flanged products. Estimation of the filling time needed to information on the confidence of filling / confidence in product quality that will occur from the setting parameters used can also be done. By using CFD, many expensive and time-consuming physical experiments can be replaced by fast and efficient simulations.

Results and Discussion

CFD analysis results

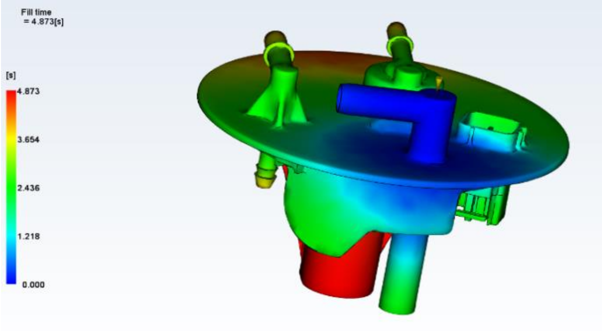
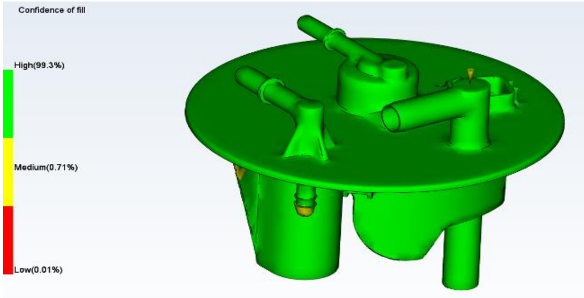


Figure 2
Fill time analysis

Filling the plastic resin into the mold, takes 4.87 seconds.



Gambar 3
Analysis Confident of fill

Based on the setting parameters used, the confidence of filling is 99.3%.

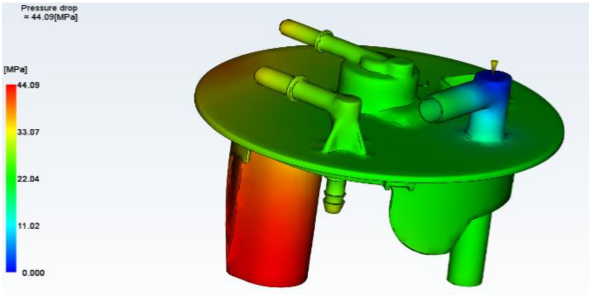


Figure 4
Pressure drop analysis

The pressure drop that occurred was 44.09 Mpa.

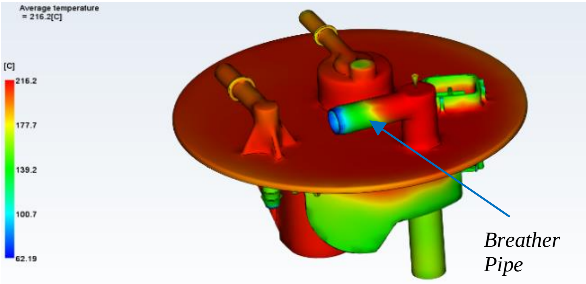


Figure 5
Temperature uniformity analysis

The average temperature is 216.2^{oC,} but in the *breather pipe area,* there is a large enough temperature difference so there is the potential for delamination due to the lack of integrity between layers.

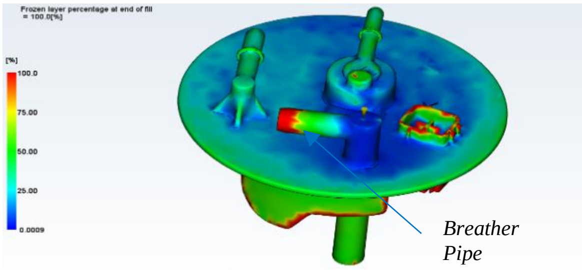


Figure 6
Frozen Layer Analysis

In the *breather pipe area*, there is a difference *in the frozen layer* on 1 surface.

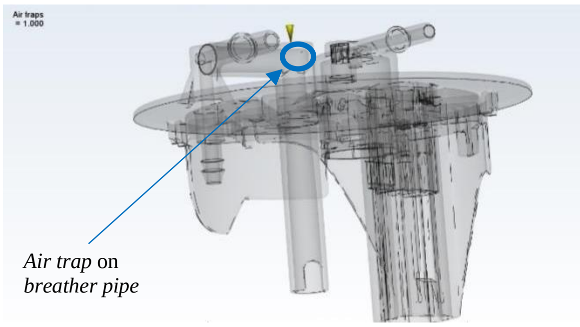


Figure 7
Analysis *of Water Traps* / trapped air

Air traps occur in the breather pipe area, this has the potential to cause voids due to gases that cannot get out of the mold.

From the results of the CFD analysis, it can be seen that although the confidence of fill is very good (99.3%), in the breather pipe area there are potential problems due to the occurrence of temperature inhomogeneity, frozen layer, and the presence of air traps. The pressure drop value that occurs (44.09 Mpa) and the filling time required (4.87 seconds) are still below the actual value of the setting parameters on the injection machine so it is still considered safe and proven by the weight stability of the product.

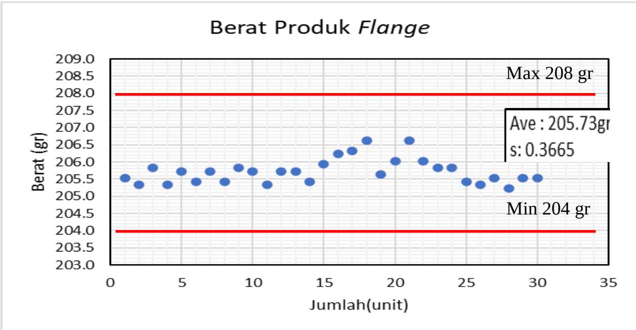


Figure 9 Weight Stability of *Flange Products*

Plastic debris appear due to a thin *flash* in the parting line area near the *gate* that is easy to come off. The plastic debris that are sticky are also affected by the new resin material.

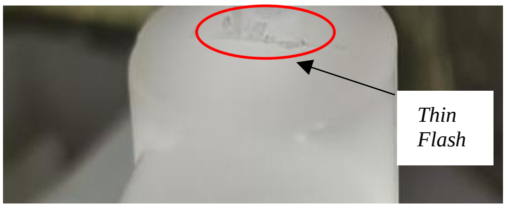
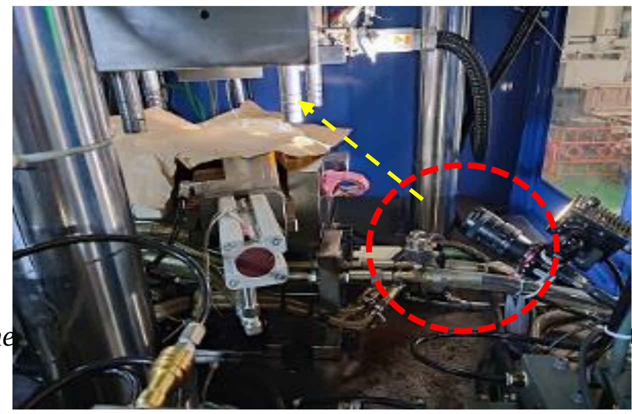


Figure 10
Thin Flash occurs on the parting line due to the failure of the slider core part

Ensuring the source of plastic debris from the cylinder injection process and hot runner is carried out by checking the high speed camera through the mold purging method.



Setting parameter used :
Screw metering (SM) = 105 mm
Velocity (V) = 10 mm/s

High Speed camera position

Figure 11
Checking foreign materials with a high speed camera

The results of the examination are as follows:

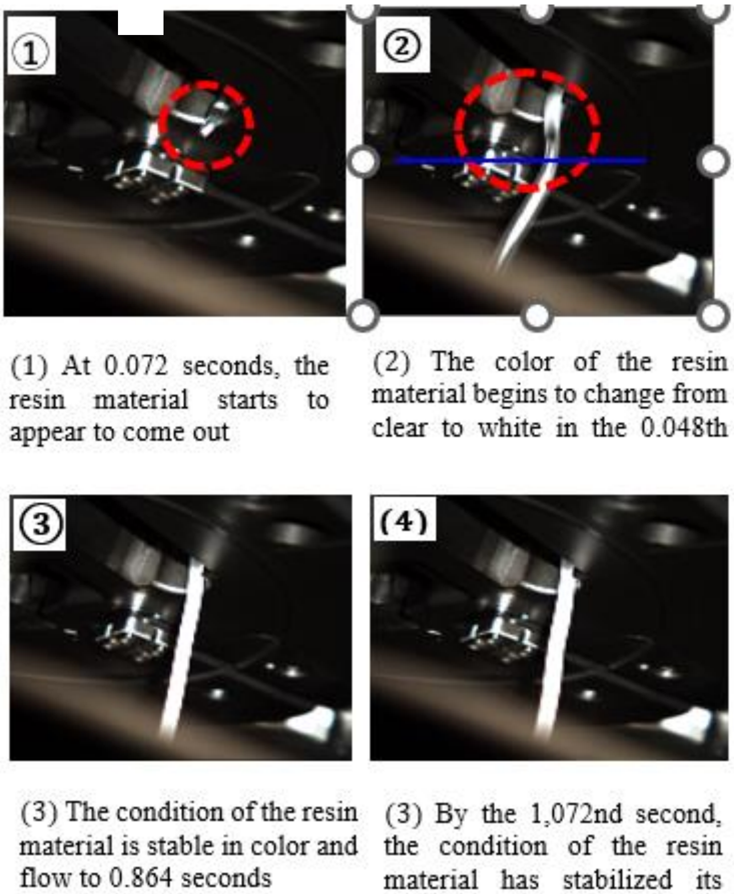


Figure 12
Results of checking foreign materials with high speed camera

From the results of checking the high camera, there was no foreign *material* , *bubbles* or delamination. Failure mechanism on *core scratch slider* and gas *burn problem*:

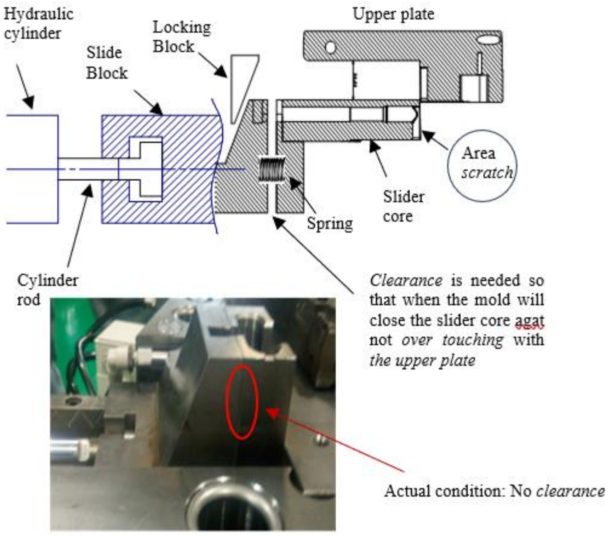


Figure 12 Mold Mechanism when closing

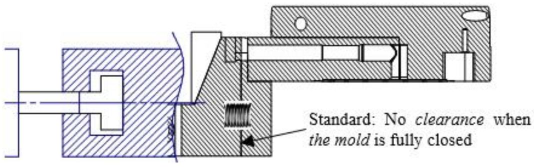


Figure 13
Mold Mechanism when full close

Solution:

1. Eliminates thin flashes that easily fall off with the repair of the slider core to normal conditions.
2. Modification of cylinder rod to provide clearance of 0.5 mm.
3. The addition of gas vents in the slider area with a vacuum system to eliminate air traps as the cause of gas burn.

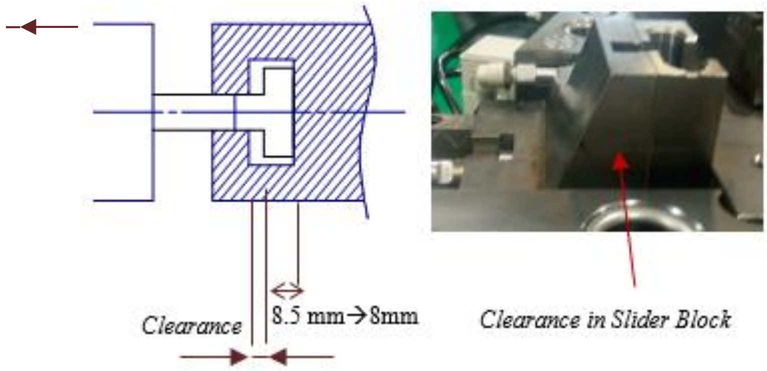


Figure 14
Cylinder *Rod Modification*

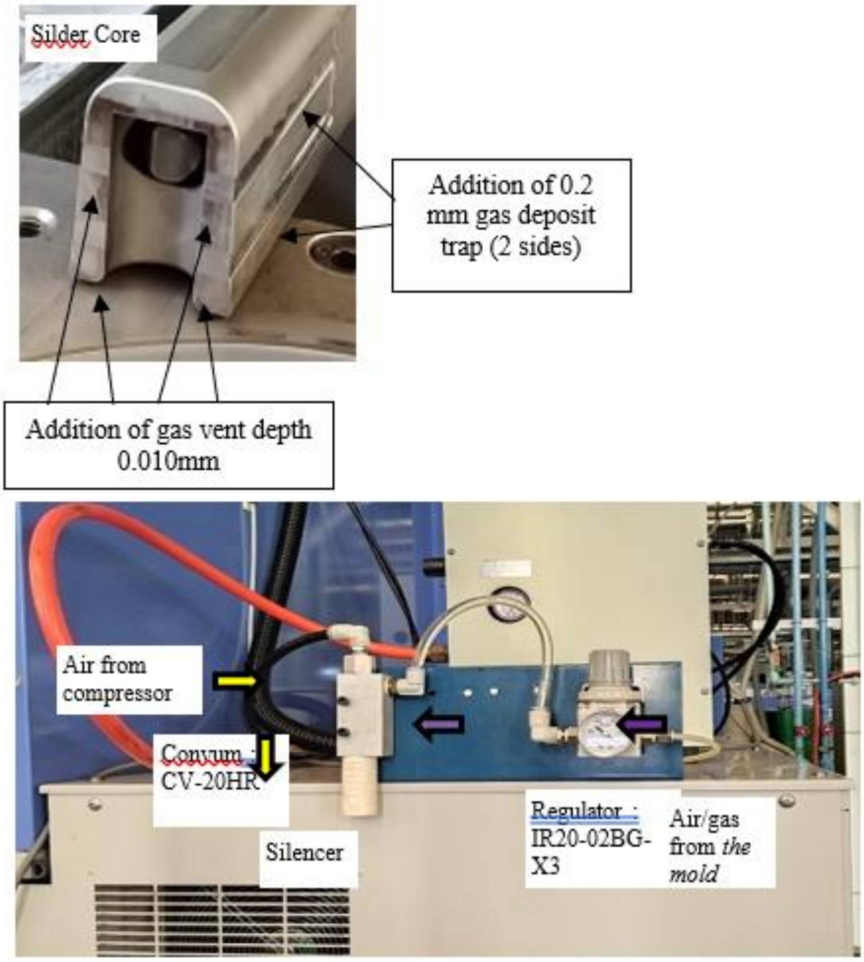


Figure 15
Addition of a gas vent to the slider core with a vacuum system

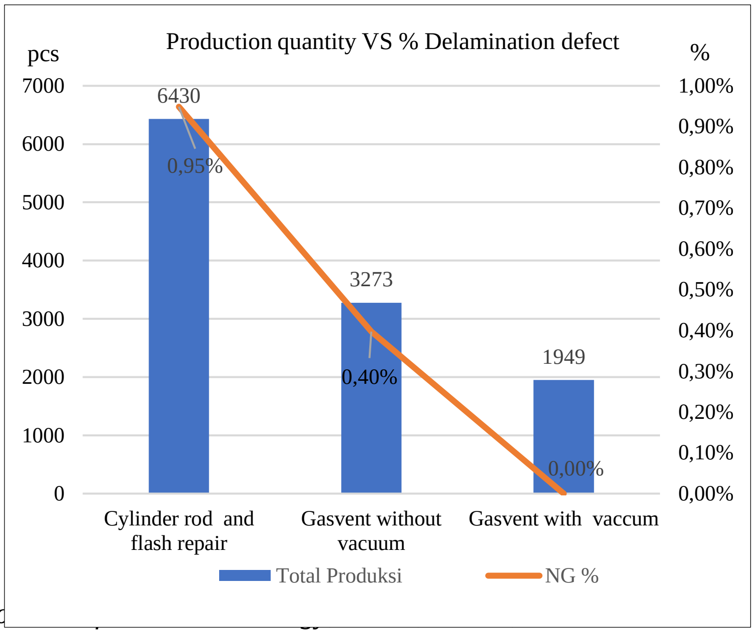


Figure 16
Graph 2 Production Data after 3 stages of improvement

A 100% visual inspection is carried out to check the delamination throughout the production process. X-ray and microscopic /SEM testing is also carried out to ensure that there are no significant voids in the breather pipe and that the integrity between the layers of the material is maintained.

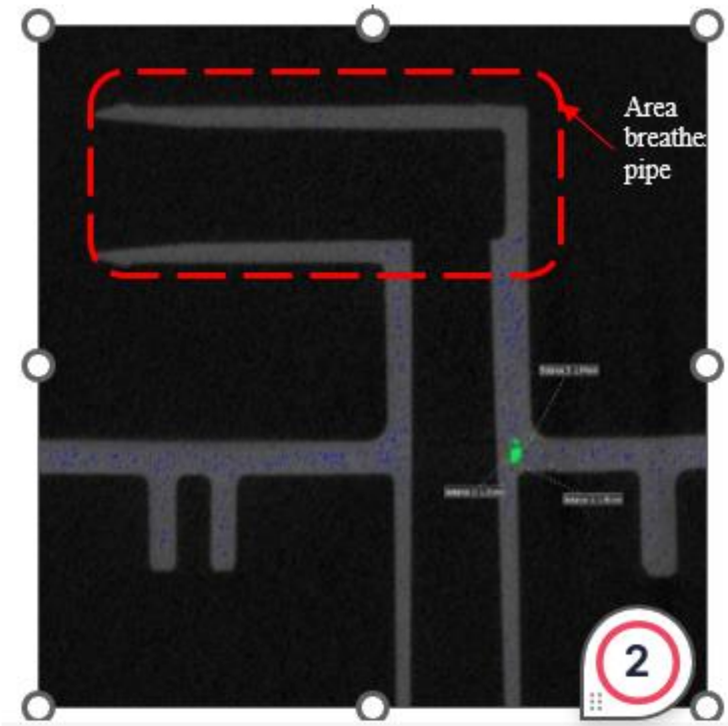


Figure 16
Void inspection by X-ray
There is no void in the breather pipe area

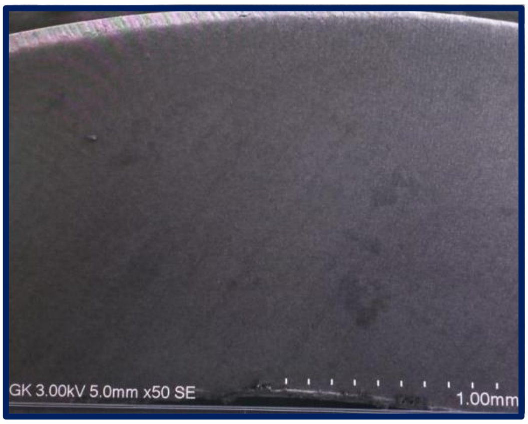


Figure 17
Integration inspection between layers of the inside of the breather pipe with SEM 50x magnification

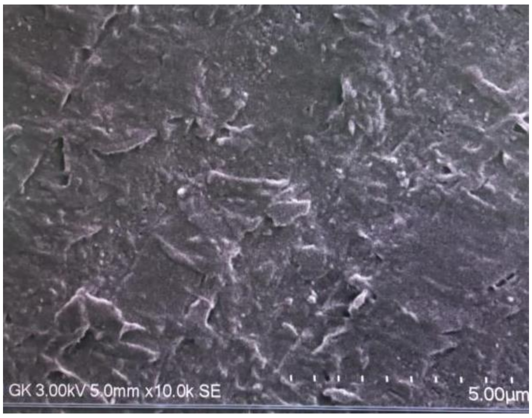


Figure 18
Inspection of the integration between layers of the inside of the breather pipe with SEM magnification 104x

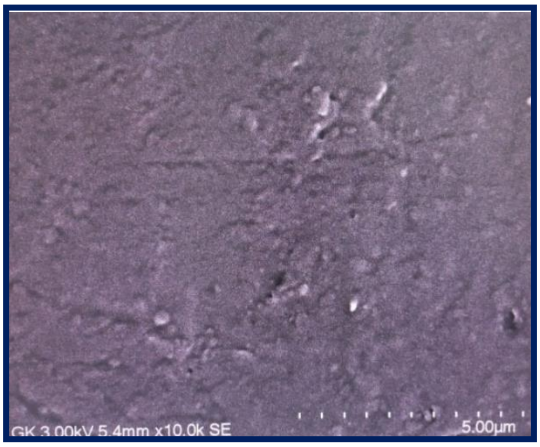


Figure 19
Inspection of the surface of the breather pipe in areas where delamination often occurred in the past with SEM magnification 104x.

In the SEM results, no voids were found, the integration between the layers was good and no delamination was obtained.

Conclusion

CFD analysis is very helpful in identifying the cause of delamination through the simulation of fluid flow and the distribution of temperature and pressure into the mold so that areas with high interlaminar stress due to high temperature differences can be identified. The main cause of delamination in the breather pipe part of flange products is foreign materials/foreign objects, both in the form of plastic debris and dirt/gas burn deposits. From the production results after 3 stages of improvement, the percentage of delamination decreased from 3.77% to 0%. The results of x-ray and microscopic/SEM tests showed that there were no void problems due to air traps or integration between layers. Periodic maintenance of the mold and cleaning of the gas vent area and gas deposit trap on the slider core must be done regularly and periodically so that the problem of delamination does not reappear in the future.

Bibliography

Badarisman, A. H., Hamid, K. Abdul, Ideris, H., Bakar, M. Abu, & Jalar, A. (2022). Effects of molding temperature on delamination of small outline transistor (SOT). *Journal of Physics: Conference Series*, *2169*(1), 12035. IOP Publishing.

Ghorpade, Kabirdas B., & Shinde, Sharda M. (2022). Glass Delamination in sterile formulations and Drug Recalls: A Review. *International Journal of Pharmaceutical Sciences and Developmental Research*, *8*(1), 1–5.

Iswanto, Adi, Rambe, M., Jabbar, A., & Ginting, Elisabeth. (2013). Aplikasi metode Taguchi Analysis dan failure mode and effect analysis (fmea) untuk perbaikan kualitas produk di PT. XYZ. *Jurnal Teknik Industri USU*, *2*(2), 219330.

Katkhede, Rahul R., Raut, Abhijeet A., & Labade, Kalyan. (2017). Defects and Solution of Plastic Parts during Injection Mouding. *International Journal for Scientific Research & Development*, *5*(09), 436–439.

Myers, Mason, Mulyana, Rachmat, Castro, Jose M., & Hoffman, Ben. (2023). Experimental Development of an Injection Molding Process Window. *Polymers*, *15*(15), 3207.

Permana, Henry, Topan, Topan, & Anwar, Syahrul. (2021). Produksi Proses Komponen Plastik Flip Flop Dengan Mesin Injeksi Molding Type Hidrolik. *Jurnal Baut Dan Manufaktur: Jurnal Keilmuan Teknik Mesin Dan Teknik Industri*, *3*(02), 8–17.

Prasad, P. Durga Ravi. (2021). Analyzation Of Various Local Surface Defects In Injection Moulding Process. *REX-ISSN 2321-1067*, 9.

Wang, Rong Tsu, Wang, Jung Chang, & Chen, Sih Li. (2022). Investigations on Temperatures of the Flat Insert Mold Cavity using VCRHCS with CFD Simulation. *Polymers*, *14*(15), 3181.

Yilmaz, Galip, Yang, Huaguang, & Turng, Lih-Sheng. (2019). Injection molding of delamination-free ultra-high-molecular-weight polyethylene. *Polymer Engineering & Science*, *59*(11), 2313–2322.