Team #22

Automated Vision System for Die Casting Quality Control

Team Members: Bryan Coe, Hanna Hatfield, Hyo Eun Lee, Quds Al Hunidi, Nino Chen, William Bosma
SOET Mentor: Milton Aguirre **Client:** Corey Vian

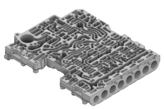
STELLANTIS

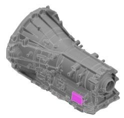
Team #22

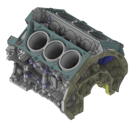
PURDUE UNIVERSITY

CUSTOMER BACKGROUND

The Stellantis Kokomo Casting plant is the world's largest die-cast facility. The plant was completed and began production in 1965 with expansions in 1969, 1986, 1995 and 1997. They create products such as Aluminum parts for automotive components, transmission and transaxle cases and engine block castings. On Feb. 28, 2023, Stellantis announced that it will invest a total of $155 million in three Kokomo, Indiana, plants to produce new electric drive modules (EDM) that will help power future electric vehicles assembled in North America.

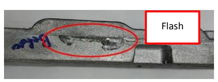

Valve Body

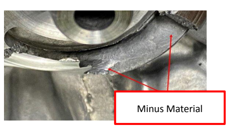

Transmission Casing

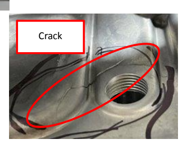

Engine Block

PROBLEM STATEMENT/ SCOPE OF WORK

The current human visual inspection process at Stellantis poses many defects which reduces the reliability of the company's die-casting technology. With the manual inspection processes, it is difficult to pinpoint certain defects that the human eye cannot clearly see or those that are borderline in terms of acceptability. To improve on this process, Stellantis is seeking an automated vision system that acquires high-quality images of every side of the valve bodies in order to accurately detect defects. This process must be within the cycle time of the part of about 120 seconds. The team is responsible for the electrical and mechanical production of the vision system, whereas graduate student B. Zhang is responsible for the AI algorithm for defect detection.





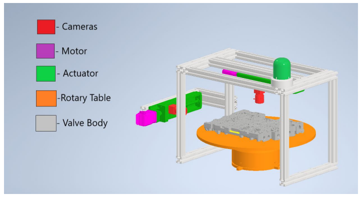


REQUIREMENTS

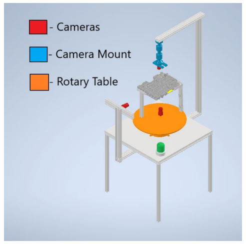
Req. #	DESIGN REQUIREMENTS	DESIGN TARGETS	VALIDATION
	RATIONAL		
1	Low cost system	Less than $1000	invoices
	High costs lead to lower profit		
2	No added cycle time	Cycle time remains the same (range of 60 seconds – 2.5 min for the largest die castings)	Measure cycle time after installation (during performance test)
	Added cycle time means less throughput, and less parts for car production		
3	Highly accurate system	High enough resolution that all defects can be detected. (Resolution 1080P)	Find high resolution cameras and ideal placement for 100% inspection, then test the images against the graduate team's software
	In order for the algorithm to detect the defects, images taken must be clear without flares, obsecurred, etc.		
4	Consistent distance/background from block	Distance must be over 7 inches in order to capture the entire product in the camera field of view	algorithm performance / technology test
	The graduate students' algorithm needs a stable and consistent background for easy detection		
5	Dimension Dependant Fixtures	Fixtures that can fit differently shaped valve bodies	Fixture fits 5 or more parts.
	Fixture design will need to be dimension dependant due to locator points on parts to ensure that the product is placed in the same location every time		
6	Indicator to inform operator that the inspection process is complete	Indicator lights need to be on the top of the frame	Prototype will be tested at the plant to ensure the operators know light specifications
	Indicator lights will be added for safety and operational organization		

EXPERIMENTATION AND CONCEPTS

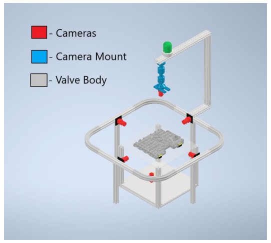
Concept 1: 2 cameras, 2 actuators, & rotary table



Concept 2: 3 cameras & rotary table

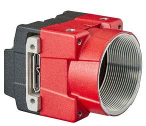


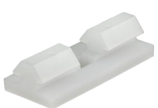
Concept 3: All cameras & no movement

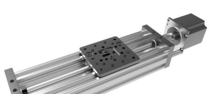


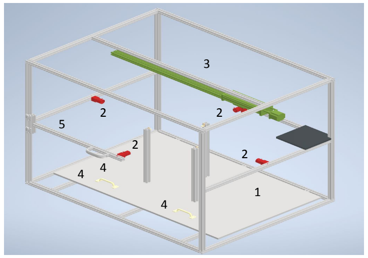
FINAL DESIGN

Key Components


Alvium 1800 U500m


UHMW Low Friction Slides


1000 mm Actuator



Fixture Design Created in CAD

Major Components	
1	Movable frames for ergonomics
2	Stationary cameras for stable, clear images
3	Linear actuator (as proof of concept) for long and larger parts
4	Handles to easily move base
5	Magnet to lock in 80-20 hinged piece

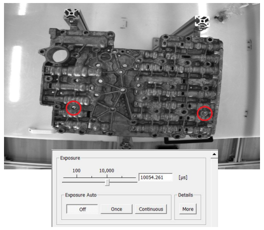
FMEA

FAILURE ANALYSIS (STEP 4)				RISK ANALYSIS (STEP 5)					
1. Failure Effects (FE) to the next Higher Level Element and/or	Severity (S) of FE	2. Failure Mode (FM) of the Focus Element	3. Failure Cause (FC) of the Next Lower Element or Characteristic	Current Prevention Control (PC) of FC	Occurrence (O) of FC	Current Detection Controls (DC) of FC or FM	Detection (D) of	DFMEA AP	Filter Code
Part could fall off or slider could break the structure	4	The inside slider.	Parts being too heavy or misuse of the slider	Extra bolts connected to the slider and frame	4	Visual	3	L	
Strain on the operator	6	The slider not being able to go all the way to the operator	Structure not being built to industry ergonomic standards	Re-evaluating ergonomics after being built	3	Visual	3	L	
Output blurry images	4	Camera goes out of focus	Glass getting scratched	Not putting camera close to where the valve body needs to be inserted	6	Waiting until image is processes and inspecting for blurry images	6	M	
Result in overexposed images (limited details)	3	Light is unadjusted to the right brightness level	The turn knob is accidentally turned	Light is manually set to desired brightness level before mounted and tested with light meter.	6	Output of images (overexposure) or light meter measurements	5	M	
Result in dark areas in image	3	Light's direction is moved resulting in diagonal exposure and shadows.	The light's direction is unstable due to low tightening of part to structure.	Manually tightening the camera to the structure	6	Waiting until image is processes and inspecting for blurry images	5	L	
Top camera does not move	5	Incorrect wiring	Only a portion of the part will get scanned	Reading the datasheet before wiring the circuit	5	Visual inspection	5	L	
Part could fall off or slider could get stuck	6	80-20 and slider interaction	Parts being too heavy or misuse of the slider/base movement.	lubricating the sliders before insertion	6	Moving the sliders and checking for continuity	6	M	
camera moves slowly and wastes time	3	Needs lubrication	Environment gets louder and image output could be off.	extreme lubrication before installation	6	Audibly listen for loud noises in the system	3	H	

TESTING

Image Acquisition

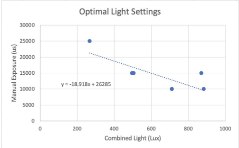
Linear actuator slowly glides with the camera attached in order to capture images of the valve bodies.



Lighting

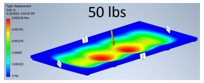
Additional light is not needed as the manual exposure rate can be adjusted

The bottom of the part (valve body) may need a light source if the lighting conditions are extremely poor.



$y = -18.918x + 26285$
user can input light in Lux received by part x to get the manual exposure setting needed y

Base Weight



The FEA concluded that there would be a max deflection of .002 inches after 50 lbs is applied to the base.

Ergonomics

The Rapid Entire Body Assessment (REBA)
For valve body placement:
Test subject is 6'2"
Neck and trunk position is 0°
Valve body is < 11lbs.
Upper arm reaches up 50°
Score A:1
Score B:4
REBA Score: 2
Score: Low risk