DESIGN & DEVELOPMENT OF FUNCTIONAL TESTING MACHINES IN JEWELLERY MANUFACTURING

Ramarao Ilavarapu

Innovations in the gems and jewellery sector have paved the way for creating and designing unique solutions that cater to increasing consumer demands for quality and value. This paper reviews the design and development of functional testing machines in jewellery manufacturing. Jewellery manufacturers face significant challenges in ensuring the quality of the products based on international standards. Worldwide, diverse types of functional tests are being performed as per the industrial standards to ensure the product reliability and durability. Sunjewels has developed a range of automated testing machines capable of ensuring reliability, durability, and functionality of various product parameters. These machines are used in testing of jewellery clasps, hinges, posts, and plating life. Some of these machines were used in adherence testing of enamel and ceramic coating which led to successful development of a new line of products.

Mr. Ramarao Ilavarapu has over 27 years of experience across diverse sectors including industrial, white goods, cutting tools, fashion, and luxury goods. He has in-depth experience in the fields of production management, manufacturing engineering, project management, supply chain management, and product development. He is currently the Senior Vice-President of Operations for Sunjewels Pvt Ltd. Ramarao has developed various systems and innovations in jewellery manufacturing. He has a degree in Mechanical Engineering and a post-graduate degree in Industrial Engineering & Management from JNTU, Hyderabad. He is also a certified professional in Strategic Management from IIM Rohtak and holds a post Graduate diploma in Business Management from NMIMS, Mumbai. He was honored with the Business Innovation Award at the Santa Fe Symposium® in 2019 and was awarded the All-India prize from KAIZEN Institute for Value Stream Implementation in 2014.

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Ramarao Ilavarapu
Senior Vice President - Operations

Shishir Nevatia, Chairman
Neeraj Nevatia, Managing Director

Sunjewels Pvt Ltd.
Mumbai, India

INTRODUCTION

The gem and jewellery industry is one of the most significant contributors to the luxury goods sector worldwide. Innovations in the gems and jewellery sector have paved the way for creating and designing unique solutions that can cater to increasing consumer demands in terms of quality and value.

Jewellery manufacturers face significant challenges while ensuring the quality of the products based on international standards. Worldwide, different types of functional tests are being performed as per the industrial standards to ensure the product reliability and durability.

The technological, regulatory, and manufacturing challenges faced by customers have driven us to design functional testing machines. Sunjewels has developed a range of semi-automated testing machines capable of ensuring reliability, durability, and functionality of the various product parameters.

BACKGROUND STUDY

Worldwide, different types of functional testing have been performed as per industrial standards to ensure the product's quality. The technological, regulatory and manufacturing challenges have driven the automotive, biomedical, and other engineering industries to perform various types of functionality testing.

The jewellery industry, being a significant part of the luxury sector, has also been facing similar challenges which has driven Sunjewels to design and develop in-house functionality testing machines.

Functional Testing can be categorized into two different forms as per the parts and requirements:

1. Destructive Testing - aims to deform or destroy a material to analyse it's point of failure.
2. Non-destructive Testing - (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system.

The need for functional testing is vital in validating the quality and functionality of the mechanism or product. Through these tests, the quality assurance team can verify the functionality based on the part requirements specification (PRS) and ensure the system functions as per the customer's requirements.

It is difficult to verify the fineness and mechanism of an item by purely visual inspection. Hence, purity and testing must be assessed through a variety of assays or tests. However, different countries employ different testing protocols, which have different levels of accuracy.

Functional testing helps us understand whether each mechanism's feature works as per the standard requirement. Each function is compared to the corresponding requirement to ascertain whether its output is consistent with the end user's expectations. Testing is done by providing sample inputs, capturing the resulting outputs, and verifying that the actual outputs are as expected. The process of these tests entails the simulation of the environment in which a product is expected to operate. This is done to check and correct any issues with functionality.

PROBLEM STATEMENT

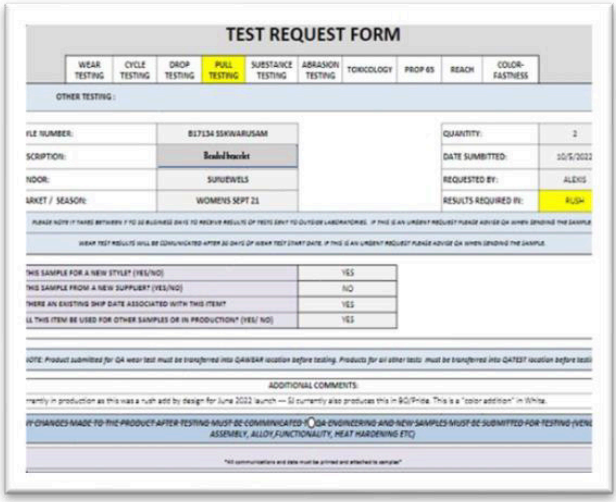
Cases of jewellery failure include peeling of coatings, failure of locking mechanisms, broken prongs, inconsistent sizing, and distorted shapes.

- Failed locking mechanisms result in a lower product life cycle and unhappy customers.
- Customers frequently express dissatisfaction with peeled off plating and tarnished products.
- Mechanical and physical properties; complaints regarding the impact, durability, hardness, strength of chains and soldering points, elongation, compression, and surface qualities.
- Failure to achieve desired durability of ceramic and enamel coated products affect new developments.

Customer Requirements

A few of our customers had raised concerns regarding the field failure of products. The first test asked by the customer was the clasp test, in which the customer needed to understand the mechanism and spring action of the clasp. Another customer asked for a durability test of vermeil plating life of the product.

Below, for reference, is the requirement received from the customer.



TEST REQUEST FORM

WEAR TESTING	CYCLE TESTING	DROP TESTING	PULL TESTING	SUBSTANCE TESTING	ABRASION TESTING	TOXICOLOGY	PROP 65	REACH	COLOR-FASTNESS

OTHER TESTING :

FILE NUMBER:	B17134 SSKWARUSAM	QUANTITY:	2
DESCRIPTION:	Beaded bracelet	DATE SUBMITTED:	10/5/2022
VENDOR:	SUYUEWELS	REQUESTED BY:	ALEXIS
MARKET / SEASON:	WOMENS SEPT 21	RESULTS REQUIRED BY:	RUSH

PLEASE NOTE IT TAKES BETWEEN 7 TO 10 BUSINESS DAYS TO RECEIVE RESULTS OF TESTS SENT TO OUTSIDE LABORATORIES. IF THIS IS AN URGENT REQUEST PLEASE ADVISE QA WHEN SENDING THE SAMPLE

WEAR TEST RESULTS WILL BE COMMUNICATED AFTER 30 DAYS OF WEAR TEST START DATE. IF THIS IS AN URGENT REQUEST PLEASE ADVISE QA WHEN SENDING THE SAMPLE

IS THIS SAMPLE FOR A NEW STYLE? (YES/NO)	YES
IS THIS SAMPLE FROM A NEW SUPPLIER? (YES/NO)	NO
IS THERE AN EXISTING SHIP DATE ASSOCIATED WITH THIS ITEM?	YES
WILL THIS ITEM BE USED FOR OTHER SAMPLES OR IN PRODUCTION? (YES/ NO)	YES

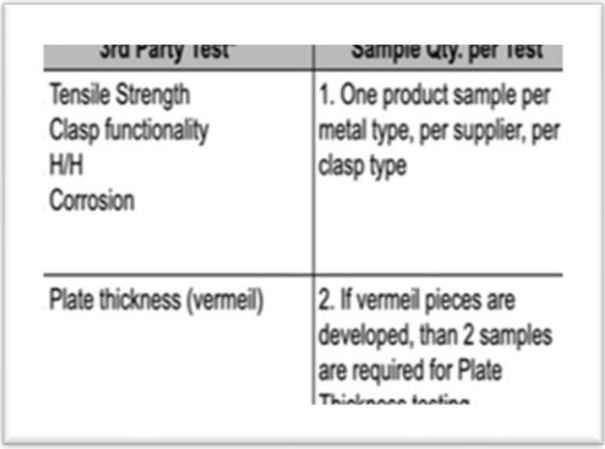
NOTE: Product submitted for QA wear test must be transferred into QAWEAR location before testing. Products for all other tests must be transferred into QATEST location before testi

ADDITIONAL COMMENTS:

currently in production as this was a rush add by design for June 2022 launch — SI currently also produces this in BG/Pride. This is a "color addition" in White.

ANY CHANGES MADE TO THE PRODUCT AFTER TESTING MUST BE COMMUNICATED TO QA ENGINEERING AND NEW SAMPLES MUST BE SUBMITTED FOR TESTING (VEND ASSEMBLY, ALLOY,FUNCTIONALITY, HEAT HARDENING ETC)

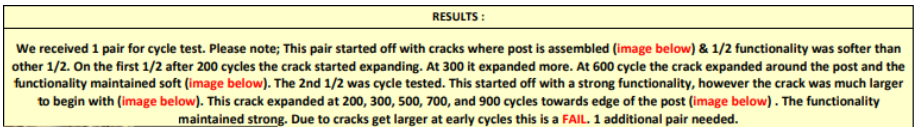
All communications and data must be printed and attached to samples



3rd Party Test	Sample Qty. per Test
Tensile Strength Clasp functionality H/H Corrosion	1. One product sample per metal type, per supplier, per clasp type
Plate thickness (vermeil)	2. If vermeil pieces are developed, than 2 samples are required for Plate Thickness testing

Figure 1: Customer Requirement Forms

To address customer concerns, Sunjewels incorporated a testing framework having both destructive and non-destructive types of testing as per their part specifications and product variations. This resulted in the acquisition of necessary testing machinery and the in-house development of functional testing machines.


RESULTS :

We received 1 pair for cycle test. Please note; This pair started off with cracks where post is assembled (image below) & 1/2 functionality was softer than other 1/2. On the first 1/2 after 200 cycles the crack started expanding. At 300 it expanded more. At 600 cycle the crack expanded around the post and the functionality maintained soft (image below). The 2nd 1/2 was cycle tested. This started off with a strong functionality, however the crack was much larger to begin with (image below). This crack expanded at 200, 300, 500, 700, and 900 cycles towards edge of the post (image below) . The functionality maintained strong. Due to cracks get larger at early cycles this is a FAIL. 1 additional pair needed.

Figure 2: Customer Test Cycle Report

After receiving the testing requirements, the following procedures are followed.

1. Understand the functional requirements.
2. Identify test input or test data based on requirements.
3. Compute the expected outcomes with selected test input values.
4. Execute test cases.
5. Compare actuals against expected standards.

FUNCTIONAL TESTING FRAMEWORK

The machine setup and testing framework was implemented as per the requirement of customers, depending on their functions and mechanisms, to ensure longer product life cycles.
The following machines have been developed and/or procured in Sunjewels Testing lab.

Machinery developed in-house

- Butterfly and Post Testing Machine
- Rub Testing Machine
- Hinge Testing Machine
- Clasp Testing Machine
- Flexible Bangle Testing Machine
- Spin Testing Machine
- Hoop Testing
- Impact Testing Machine
- Drop Test

Machinery procured from external vendors

- Universal Testing Machine
- Vickers Hardness Tester
- Extreme Temperature Test
- XRF Test

TESTING MECHANISM

The tests are performed as per the part requirement or mechanism of the item or as per the design standards. This is the best way to check the life cycle of the item (which in turn would improve the organization's ability to give better service to the customer) and to empower customers to check their own product quality. Also, to get information and knowledge on every design that they work on.

Below is the reference test requirement form.

SUNJEWELS PVT LTD

Format No.: F/QAU/FT/02
Revision No.: 01
Revision Date: 23.11.2022

FUNCTIONAL TEST REQUEST FORM

est to be performed (must mark (✓) below):

Surface Hardness Test	Wear Test	Cycle Test	Drop Test	Pull / Compression Test	Rub Test	Mechanism Test	Extreme Temp. Test	Impact Test	Colour Fastness	Other Test

tyle Number:		Bag No.:		Quantity:	
roduct Description:				Date of Submitted:	
ustomer Code:				Requested By:	
ustomer Specifications / dditional Req. (if any) :					
est Method if provided by customer or SJ tandard Reference :					

Please note it takes between 2-3 working days to performed the test and accordingly the report will be submitted.
The test duration and pieces required depends on the test to be perfomed (same is been droppped on mail)

s this sample for New style? (Yes/No)	
s this sample from New Customer? (Yes/No)	
s there an existing ship date assosciated with this item?	
Will this item be used for other samples or in production? (Yes/No)	

ANY CHANGES MADE TO THE PRODUCT AFTER TESTING MUST BE COMMINICATED TO QA ENGINEERING AND NEW SAMPLES MUST BE SUBMITTED FOR TESTING (ASSEMBLY, ALLOY,FUNCTIONALITY, HEAT HARDENING ETC)

"All communications and data must be printed and attached to samples"

"NO NEW MATERIALS SHOULD BE UTILIZED BY DESIGN UNTIL ALL APPROPRIATE TESTING HAS BEEN COMPLETED"

Figure 3: Functional Test Request Form

	SUNJEWELS PVTLTD		Doc. No.:SJ-QA/SOP/FT/01Rev. No.:01 Rev. Date:19.09.2022
	STANDARD OPERATING PROCEDURE FOR FUNCTIONAL TEST		*Page-01- 02*
1-Objective:	To test the functions of mechanisms and analysis.		
2- Scope:	The scope covers product specific functional tests required as per customer specifications.		
3-Responsibility:	Quality Control Authority: HOD- QA/QC Operations		
4-Procedure:	4.1-Functional Test is performed to check the durability and functionality of the product.		
	4.2-Fortest, details asper customer requirement or SJ standard to be provided by concerned functional department to quality.		
	4.3-Functional Test is carried out after receiving the test requisition form.		
	4.4- The Functional Test will be performed as per the Sun Jewels Standard which is mentioned below or by Customer Specifications/ Requirement (if any).		
	4.5- Functional Test is done in three different stages like:1-Inward Stage 2- Sample Stage 3- Pilot /Production Stage		
	4.5.1-The sampling plan is as mentioned below based on ISO2859:1 1- Inward Stage: Random sampling of 2 Pieces will be used for testing from every batch. 2- Sample Stage: At least One Piece of every design should be tested as per the design requirement. 3- Production Stage: Sample should be tested as per sampling plan.		
	4.5.2- Functional Test : Pull test to be carried out for chains, Rub test to be carried out for Gold plated, Silver Plated, Ceramics or Enamel pieces, Butterfly test to be carried out for earrings.		
	4.5.3-Pulltest specification: Depends on the thickness of chains, minimum load should sustain is 2.26 Kg. Butterfly Wear Test: Test run for 1000 cycles should be performed & the mechanism should not be loose after completing the test run. Clasp functionality Test: Test run for 1000 cycles should be performed & the mechanism should not fail after completing the test run. Rub Test- Test run for 1000 strokes should be performed &coating should not wear off after completing the test run. Bangle Hinge Test- Test run for 1000 cycles should be performed & function should not be affected after completing the test run. Flexible Bangle Test-Test run for1000 cycles should be performed & function should not be affected after completing. The test runs.		
	4.5.4-Sample size for Functional test: 1. PullTest:1 2. Clasp Functionality:1 3. Butterfly wear Test: 1 4. Drop and Impact Test:2 5. Spin Test:1 6. Flexible Bangle:1		
	4.6-After performing the required test, the test report will be shared with images of material (i.e.before test and after test).		
Prepared By-	Manoj Kumar Gupta	Date-	15.09.2022
Reviewed By-	Ravindra Kamath	Date-	19.09.2022
Approved By-	I.V. Ramarao	Date-	20.09.2022

Figure 4: Functional Testing SOP

IN-HOUSE DEVELOPED FUNCTIONAL TESTING MACHINES OVERVIEW

The various machines used in Sunjewels depend on the mechanism and function of the pieces. Each machine has its own set of parameters set up by Sunjewels. The parameter has been set up by checking the physical usage of the pieces and by collecting the world-class quality guidelines of the customer's requirements. The machines are programmed to check the exact lifetime of the pieces produced by Sunjewels using cutting-edge technology. Every

machine operates on specific mechanisms and principles which will be briefed in the next section.

Jewellery components, like bangle hinges and clasps, are more than mechanisms to simply hold pieces together. They are key to functionality and aesthetics of the jewellery pieces.

These mechanisms work on revolving around a fixed axis. Thus, design of the testing equipment for these components is based on dynamics of the rotational motion about a fixed axis. Rotational motion can be defined as the motion of an object around a circular path, in a fixed orbit.

A slider-crank mechanism is a typical design which converts rotary motion into linear motion. It is achieved by connecting a slider and a crank with a rod. This mechanism is also utilized as a system that converts the reciprocating linear motion.

In the diagram below, the rotation of the crank drives the linear movement of the slider.

It is widely used in various applications, including internal combustion engines, pumps, compressors, presses, robotics, toy cars, and human-powered vehicles.

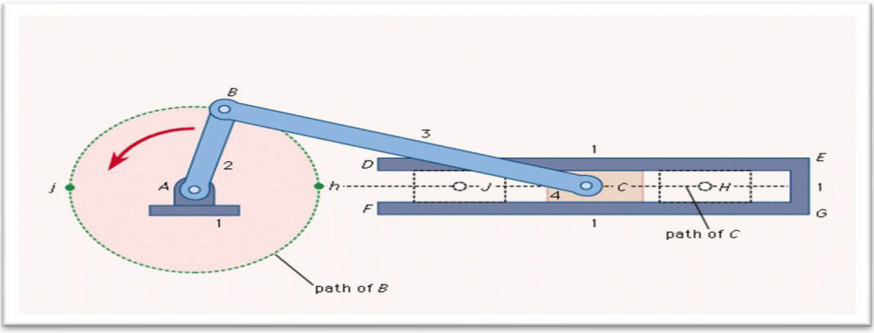


Figure 5: Slider Crank Mechanism

Clasp Testing Machine

Jewellery clasps are used to fasten necklaces and bracelets. The durability of the clasp is crucial for extending the life of jewellery. Broken clasps, worn out toggles, damage to the safety notch are a few of the repetitive damages observed in clasps.

Figure 6: Clasp Testing Machine

Bill of Material

This machine includes On / OFF Knob (Machine Activation), Counter: KTC443 'I Therm', SPDT Toggle Switch, Transparent Acrylic Strip for 6 mm thickness and 20 mm broad, Cam and Follower and Motor: 20RPM, 230AC Voltage, 1 Amp Current as major components.

Principle of Operation

The rotary motion is transferred to linear motion. When the machine arm moves forward, the clasp notch is pressed. The same machine arm will return by the spring action inside the clasp. This completes one test cycle. The proximity sensor detects the motion of connecting plate and gives a pulse. The counter records number of cycles. Based on cycle required per minute, the motor speed is controlled by the speedometer.

Figure 7: Manual Testing

Figure 8: Mechanized Testing

Bangle Hinge Testing Machine
The hinge mechanism allows you to open and close your bangle on a repeated basis. Certain bracelets have a simple hinge that opens easily, relying on a clasp to close the bangle. Other bangles rely on a spring hinge that has tension, allowing the bracelet to close by "springing" right back.

During the review of customer complaints regarding the bangle hinges, cases of tight hinging, moving components, worn out hinges were observed. This was the result of poor assembly work, excess soldering and completion of product life cycle.
To address these concerns, Sunjewels has manufactured a bangle hinge testing machine.

Figure 9: Bangle Hinge Testing Machine

Bill of Material
This machine includes Counter: KTC 443'I Therm', Proximity Sensor: (RP-LM08_300PA), Motor: 20RPM, 230AC Voltage, 1 Amp Current, Cam and Follower and SPDT Toggle Switch as major.

Principle of Operation
When the motor begins to rotate, rotational motion is converted into linear horizontal motion by the Cam and follower. This motion

is transferred to a bent aluminum strip. When the strip moves forward, the “C” side of the bangle gets open, which is fixed to the fixture. And then the same strip will return by closing the Bangle. This completes one cycle of tests. Mechanisation makes it possible to perform closing and opening operation of Bangle Hinge-Tester at a much faster rate.

The proximity sensor detects the motion of the connecting plate and gives a pulse to the counter, which counts the number of cycles. The speed controller regulates the speed of the motor based on the number of cycles required per minute.

Acceptance Criteria

After 1,000 cycles (1 year) - Mechanism should not become loose. Detailed images need to be taken after every 250 cycles. The number of years vary as per the customer requirements.

Flexible Bangle Testing Machine

The flexible bangle testing machine measures the range of motion as well as the strength of enamel or ceramic coated on steel surfaces. It also helps to define the range after which the metal retains its original opening.

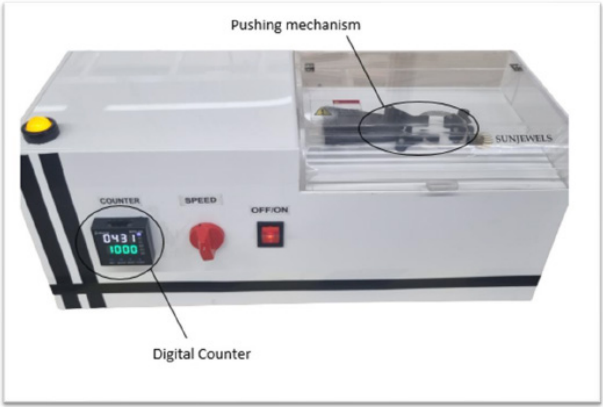


Figure 10: Bangle Hinge Testing Machine

Bill of Material

This machine includes Counter: KTC 443’I Therm’, SPDT Toggle Switch, Proximity Sensor: (RP-LM08_300PA) and Motor: 20RPM, 230AC Voltage, 1 Amp Current as major components.

Principle of Operation
The bangle opening is performed with linear motion if the motor uses machine arm. The same machine arm will return to the original position by the spring action in bangles. This completes one test cycle.

Acceptance Criteria
After 1,000 cycles (1 year) – Opening should retain its original opening. Detailed images need to be taken after every 250 cycles. The number of years vary as per the customer requirements.

Spin Testing Machine
The Spin testing machine is specially designed for testing of Pendants with rotating loop. The testing involves the measurement of torsional strength of the pendant and loop assembly.

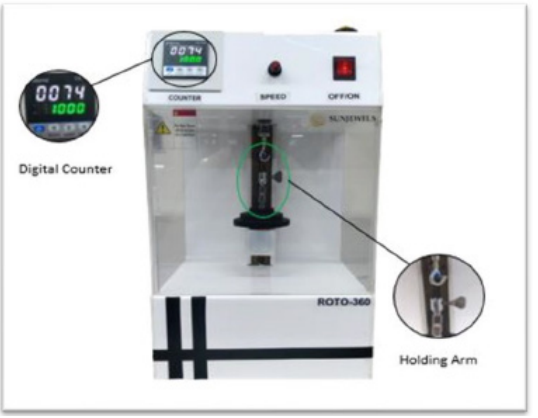


Figure 11: Spin Testing Machine

Principle of Operation
The rotary motion of the motor is transferred to a shaft which in turn helps the hook for 360° rotation. The position of the pendant is in locked jaws from base or front surface.

The proximity sensor detects the rotation of the hook and gives a pulse to the counter to measure the number of cycles.

Acceptance Criteria
After 1,000 cycles (1 year) - Mechanism should not get loose. Detailed images need to be taken after every 250 cycles. The number of years vary as per the customer requirements.

Hoop Testing Machine
The hoop testing machine measures the range of motion as well as the functionality of the hinge mechanism. It also helps us understand durability of the hoop based on number of cycles.

Figure 12: Hoop-Testing Machine

Principle of Operation
When the motor begins to rotate, the two gears mesh together to facilitate rotational motion. This mechanization makes it possible to perform rapid closing and opening operation of hoop.

Acceptance Criteria
After 1,000 cycles (1 year) – Opening should retain its original opening. Detailed images need to be taken after every 250 cycles. The number of years vary as per the customer requirements.

A pneumatic cylinder is a mechanical device that converts compressed air energy into a reciprocating linear motion. A double-acting cylinder uses compressed air to move a piston in and out, while a single-acting cylinder uses compressed air for one-way movement and a return spring for the other. Compressed air is used to move the piston in one direction, and a spring either extends the piston (A) or retracts it (B). Based on this pneumatic principle, a Butterfly Testing Machine and Rub Testing Machine has been developed.

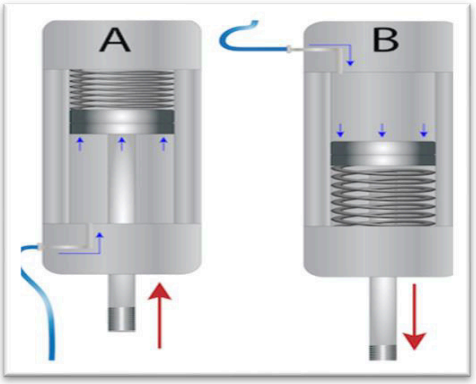


Figure 13: Single Acting Cylinder

Butterfly Testing Machine
Butterfly and post are the two main components of all kinds of earrings.

This is an in-house developed testing machine that helps us to define average life of butterfly and post.

Figure 14: Butterfly Testing Machine

Bill of Material
This machine includes Counter: KTC443 'I Therm, Cam and Follower, Speed- Regulator, Proximity Sensor: (RP-LM08_300PA) and Motor: 20RPM, 230AC Voltage, 1 Amp Current as major components.

Principle of Operation
In this machine, rotary motion of the installed motor is transferred to a nylon cube using a connecting plate. When the nylon cube moves forward, pin post fixed at another end gets into the moving

butterfly and same will get detached in the return action of the cube. This completes one cycle of test The proximity sensor detects the motion of connecting plate and gives a pulse to the counter, which counts the number of cycles. Speed controller controls speed of the motor. The number of cycles required per minute can be decided. Proximity sensor and speed controllers are used to measure pulse and control the testing speed. This enables inward and outward movement of post and butterfly at very fast rates.

Acceptance Criteria

After 1,000 cycles (1 year) - Mechanism should not get loose. Detailed images need to be taken after every 250 cycles. The number of years vary as per the customer requirements.

Rub Testing Machine

To ensure customer satisfaction for a coated or plated product, Sunjewels has manufactured a Rub test machine. The longevity of the surface finishing is one of the most critical aspects for a lasting coated product. This is a sustainability testing machine that makes products undergo a test as per their application in regular life. This helps us determine the average life of a component or product. Previously, there was no such medium or source to test products. Due to which it was not possible to guarantee the specific life of the component or product with it's original properties. Evaluating these components and products manually was a very time-consuming process. For bulk orders, it was not possible to test all the components.

To make this testing operation faster, this project was initiated.

Figure 15: Rub Testing Machine

Technical Specifications

Power Supply	230 Volt A.C
Rub Pressure	7-8 Bar
Pneumatic Air Pipe ODF	8 mm
Rub Mode	Reciprocating Movement
Rub Times	0 – 9999
Rub Speed	25 RPM
Net Weight	25 Kg
Machine Dimension	460Lx300Wx490H mm

Figure 16: Technical Specifications of Rub Testing Machine

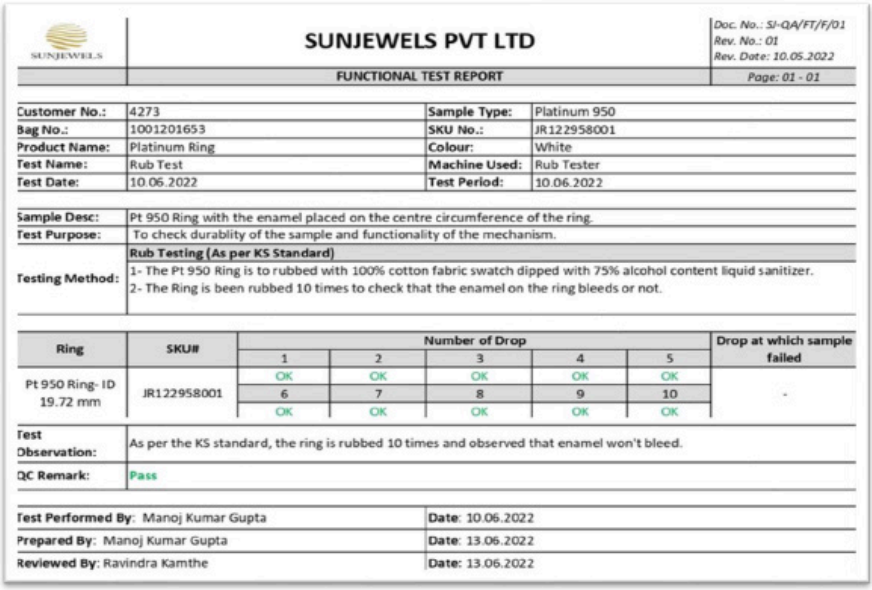
Bill of Material

This machine includes Pneumatic Cylinder of Tianyu make (100 mm stroke Max.), Pneumatic Regulator (Omron H3CR), Nylon Cylindrical Rod - Ø 20 x 200 mm long (Covered with Velcro), Roller Bearing Guide Rails and On / OFF Knob (Machine Activation) as major components.

Principle of Operation

When the motor begins to rotate, its motion is converted into linear motion by the cam and follower. This motion is transferred to a nylon roller using the connecting rod. In this machine, two samples of the same substrate are rubbed against each other in the same plane under constant pressure and at a fixed speed. The number of rubs is recorded using a non-contact digital counter.

The proximity sensor detects the motion of the substrate and gives a pulse to the counter, which counts the number of cycles. The speed controller regulates the speed of the motor based on the number of cycles needed per minute.



SUNJEWELS PVT LTD

Doc. No.: SJ-QA/FT/F/01
Rev. No.: 01
Rev. Date: 10.05.2022

FUNCTIONAL TEST REPORT

Page: 01 - 01

Customer No.:	4273	Sample Type:	Platinum 950
Bag No.:	1001201653	SKU No.:	JR122958001
Product Name:	Platinum Ring	Colour:	White
Test Name:	Rub Test	Machine Used:	Rub Tester
Test Date:	10.06.2022	Test Period:	10.06.2022

Sample Desc:	Pt 950 Ring with the enamel placed on the centre circumference of the ring.
Test Purpose:	To check durablity of the sample and functionality of the mechanism.
Testing Method:	Rub Testing (As per KS Standard) 1- The Pt 950 Ring is to rubbed with 100% cotton fabric swatch dipped with 75% alcohol content liquid sanitizer. 2- The Ring is been rubbed 10 times to check that the enamel on the ring bleeds or not.

Ring	SKU#	Number of Drop					Drop at which sample failed
		1	2	3	4	5	
Pt 950 Ring- ID 19.72 mm	JR122958001	OK	OK	OK	OK	OK	-
		6	7	8	9	10	
		OK	OK	OK	OK	OK	

Test Observation:	As per the KS standard, the ring is rubbed 10 times and observed that enamel won't bleed.
QC Remark:	Pass

Test Performed By: Manoj Kumar Gupta	Date: 10.06.2022
Prepared By: Manoj Kumar Gupta	Date: 13.06.2022
Reviewed By: Ravindra Kamthe	Date: 13.06.2022

Figure 17: Rub Test Report

Acceptance Criteria

The test is per formed as per customer requirements (i.e., for number of years). Detailed pictures are noted for data purposes. One cycle is considered when there is complete “to and from” motion of hook-and-loop fasteners. 1000 successful cycles ensure parameter durability of one year.

Impact Testing Machine (ASTM E23)

In materials science, the Charpy impact test is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the material’s toughness. It is widely used in industry since it is easy to prepare and conduct. The results can be obtained quickly and cheaply. The pendulum impact test involves the measurement of the energy required to break a test specimen that is clamped at the ends and then struck in the centre by a pendulum weight. The energy required to break the specimen is obtained from the loss in energy of the pendulum.

This energy is simply the difference in potential energy of the hammer before and after the impact which is calculated as below:

$$E_{frac} = mg\,(h_S - h_E)$$

E_{frac} = Energy required to break the specimen
m = Mass of pendulum
g = Gravity
h_S = Height of pendulum starting point
h_E = Height of the pendulum from the first reversal point

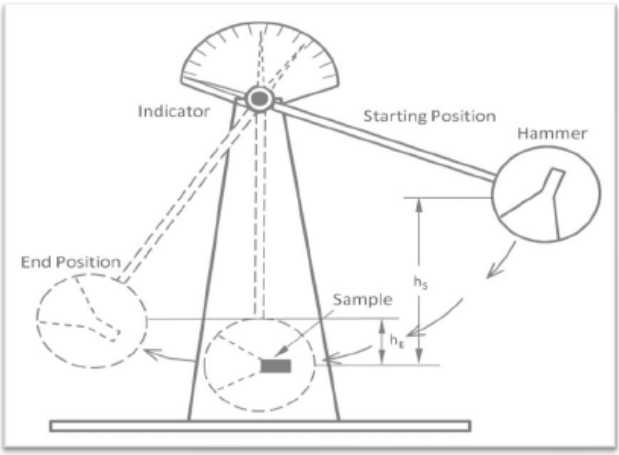


Figure 18: Charpy Impact Test

Material impact testing provides information on failure modes under high velocity loading conditions that result in a sharp fracture. There is a stressor present. The energy absorbed at a fracture is generally related to the area under the stress-strain curve, which is termed “toughness” in some references.

The purpose is to test and verify that our jewellery with ceramic, enamel or other coating can withstand the impact load against which our products can be vulnerable during the life span of their usage and provide a proof of the strength of our products up to a certain estimated value.

There is currently no provision for testing jewellery products against external impact forces in a systematic and controlled manner to derive proper results that can be justified in defining their strength and manufacturing quality.

Therefore, we have designed and developed a testing rig with our in-house capabilities that will provide a solution to this concern. The aspects to be considered during the designing of the rig are as follows:

- Maximum and minimum impact force going to be required.
- Type of products to be tested.
- Maximum and minimum size of the products which are going to be tested.
- Acquiring the C.G of impact of pendulum and specimen to be tested.
- Considering the product having a layer of ceramic coating, the following are the failure modes identified based on day-to-day life and customer perspective of product being vulnerable to certain situations.
- Free falling from a certain height.
- Tapping ring or ceramic on some hard surface repeatedly.
- Impact on ring or ceramic worn in finger, to a hard surface by swing of hand.

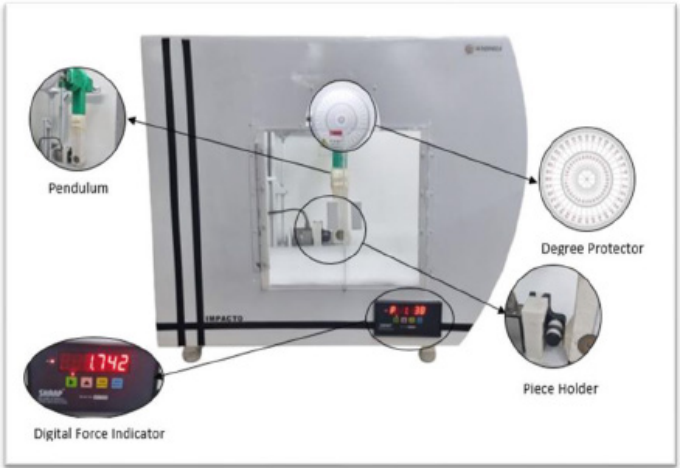
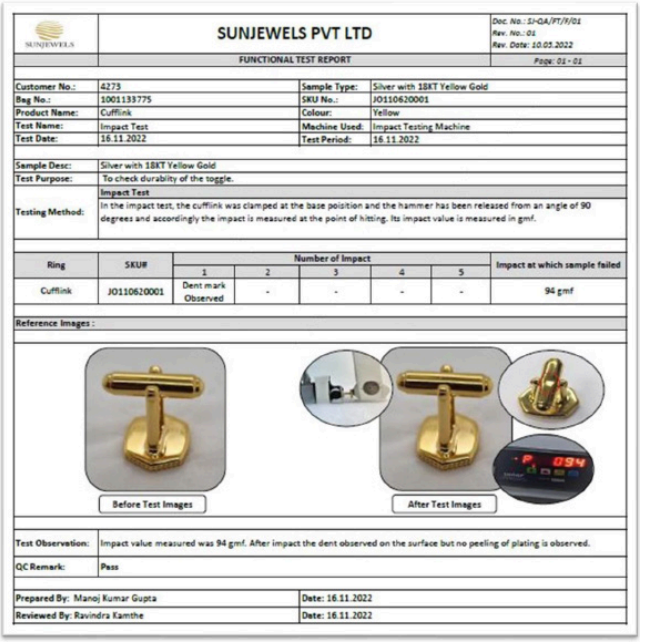


Figure 19: Impact Testing Machine

Principle of Operation

The apparatus for performing impact tests is the hammer that is released from a position at a fixed height. The specimen is placed at the base, and when the pendulum is released, it strikes and impacts the specimen, imparting an impact force, The load is

applied as an impact blow from the indicator controller's weighted pendulum value in kilograms. The machine can be used to make an impact on the ceramic surface with desired force and the value of the force can be noted from the indicator screen.



SUNJEWELS PVT LTD

Doc. No.: SJ-QA/PT/F/01
Rev. No.: 01
Rev. Date: 10.05.2022

FUNCTIONAL TEST REPORT

Page: 01 - 01

Customer No.:	4273	Sample Type:	Silver with 18KT Yellow Gold
Bag No.:	1001133775	SKU No.:	JO110620001
Product Name:	Cufflink	Colour:	Yellow
Test Name:	Impact Test	Machine Used:	Impact Testing Machine
Test Date:	16.11.2022	Test Period:	16.11.2022

Sample Desc:	Silver with 18KT Yellow Gold
Test Purpose:	To check durability of the toggle.
Testing Method:	Impact Test In the impact test, the cufflink was clamped at the base poisition and the hammer has been released from an angle of 90 degrees and accordingly the impact is measured at the point of hitting. Its impact value is measured in gmf.

Ring	SKU#	Number of Impact					Impact at which sample failed
		1	2	3	4	5	
Cufflink	JO110620001	Dent mark Observed	-	-	-	-	94 gmf

Reference Images :

Before Test Images

After Test Images

Test Observation:	Impact value measured was 94 gmf. After impact the dent observed on the surface but no peeling of plating is observed.
QC Remark:	Pass

Prepared By: Manoj Kumar Gupta	Date: 16.11.2022
Reviewed By: Ravindra Kamthe	Date: 16.11.2022

Figure 20: Impact Test Report

Acceptance Criteria

For identifying the need for testing the plating for its strength, the impact testing machine was conceptualized. With proper engineering and designing tools, the concept is implemented into a proper testing rig for the said purpose. Based on the extent of dents and scratches observed after performing test, the products are verified.

Drop Testing Machine

Drop Test is performed on the pieces or parts which are glued stones or those that are not prong set, ceramic, enamel, and all detachable mechanisms. This cycle is done to ensure that the mechanisms or functionality of the pieces should sustain as per the standard defined criteria of Sunjewels.

Figure 21: Drop Test Machine

Bill of Material

This machine includes Wooden Block with concrete floor on base, SS Scale of 6 feet height, Pneumatic Cylinder and Start - Stop Button as major components.

Principle of Operation

- Drop test manually (by hand) mimicking the same action that will be used to function the piece by the customer. Repeat the same process 5 times.
- Drop test manually (by hand) mimicking the same action that might be used by the customer. Repeat the same process for 5 drops from 5 feet.
- The drops to start from 1 foot and must be continued to 5 feet.
- Start video recording (with sound so we can hear the hit) while drop testing of all the 5 drops.
- After every drop, stop to inspect and take clear images of all conditions. Record all conditions.
- After completion of all 5 drops take images of the item from all angles and of all observations.
    - The piece should be repaired /fixed during the test cycle.

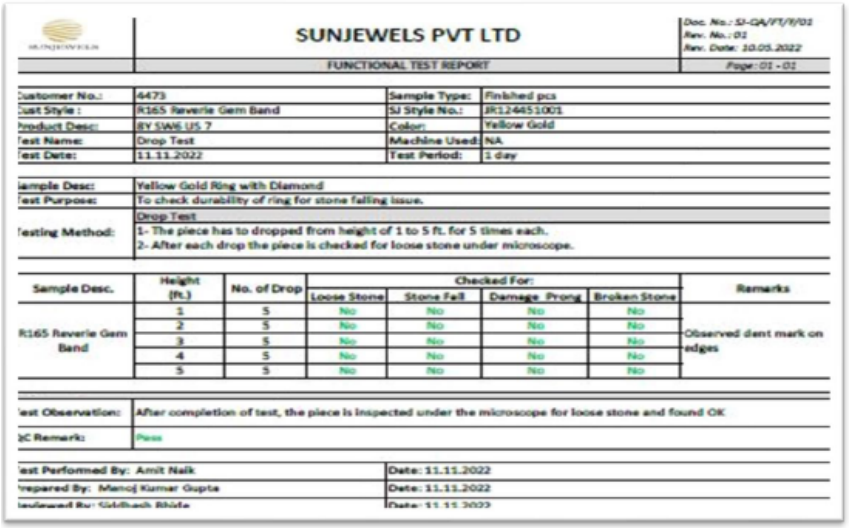
Drop Test SOP

	SUNJEWELS PVT LTD		Doc. No.:SJ-QA/SOP/DT/01Rev. No.:01 Rev. Date:19.09.2022
	STANDARD OPERATING PROCEDURE DROP TEST		*Page-01- 02*
1-Test	To perform drop test		
2- Machine:	Manual		
3-Outcome:	Durability/ Dent Resistance		
4-Procedure:	4.1-No breakage or separation after 4 drops from 3 feet onto vinyl-tiled concrete floor.		
	4.2-Take detailed images per drop.		
	4.3-No breakage or separation after 5 drops from 1 - 5 feet onto vinyl-tiled concrete floor		
	4.4- Take detailed images per drop		
Prepared By-	Manoj Kumar Gupta	Date-	15.09.2022
Reviewed By-	Ravindra Kamthe	Date-	19.09.2022
Approved By-	I.V. Ramarao	Date-	20.09.2022

Figure 22: Drop Test Standard Operating Procedure

Acceptance Criteria

After the completion of testing the product is inspected for defect parameters like loose stone, crack, diamond fall etc. The presence of any of these defects will lead to failure as per the customer defined testing criteria.



SUNJEWELS PVT LTD

Doc. No.: SJ-QA/FT/F/01
Rev. No.: 01
Rev. Date: 10.05.2022

FUNCTIONAL TEST REPORT — Page: 01 - 01

Customer No.:	4473	Sample Type:	Finished pcs
Cust Style :	R165 Reverie Gem Band	SJ Style No.:	JR124451001
Product Desc:	RY SW6 US 7	Color:	Yellow Gold
Test Name:	Drop Test	Machine Used:	NA
Test Date:	11.11.2022	Test Period:	1 day

Sample Desc:	Yellow Gold Ring with Diamond
Test Purpose:	To check durability of ring for stone falling issue.
Testing Method:	Drop Test 1- The piece has to dropped from height of 1 to 5 ft. for 5 times each. 2- After each drop the piece is checked for loose stone under microscope.

Sample Desc.	Height (ft.)	No. of Drop	Checked For: Loose Stone	Stone Fall	Damage Prong	Broken Stone	Remarks
R165 Reverie Gem Band	1	5	No	No	No	No	Observed dent mark on edges
	2	5	No	No	No	No	
	3	5	No	No	No	No	
	4	5	No	No	No	No	
	5	5	No	No	No	No	

Test Observation:	After completion of test, the piece is inspected under the microscope for loose stone and found OK
QC Remark:	Pass

Test Performed By: Amit Naik	Date: 11.11.2022
Prepared By: Manoj Kumar Gupta	Date: 11.11.2022
Reviewed By: Siddhesh Bhide	Date: 11.11.2022

Figure 23: Drop Test Result

RESULTS

Below is an example of the Monthly Summary of test results conducted at Functional Testing Lab.

Functional Test Data- November 2022 - December 2022				
Test	**Qty**	**Pass**	**Fail**	**% Fail**
Cycle Test	70	67	3	4%
Impact Test	15	13	2	13%
Drop Test	18	17	1	6%
Butterfly & Post Test	150	135	15	10%
Flexible Bangle Test	35	30	5	14%
Spin Test	1	1	0	0%
Rub Test	11	10	1	9%
Clasp test	73	71	2	3%
Hinge Test	10	10	0	0%
Total Test	383	354	29	8%

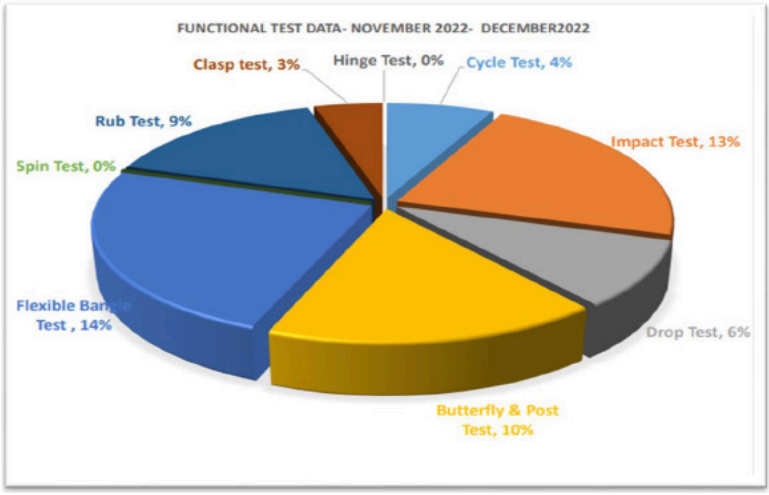


Figure 24: Functional Test Data and Chart

The critical issues are further analysed using DMAIC methods to find an appropriate solution. Once the redesigned product has passed all the requirements of testing, the products are approved for further processing.

RESULTS:
We cycle tested the bracelet 1000 times. There was no porosity observed and the bracelet still held up well without any functional issue after 1000 cycles . The bracelet PASSED the test.

Figure 25: Positive Feedback of Customer Test Cycle

Due to implementation of testing framework, we have significantly reduced the extent of customer rejections.

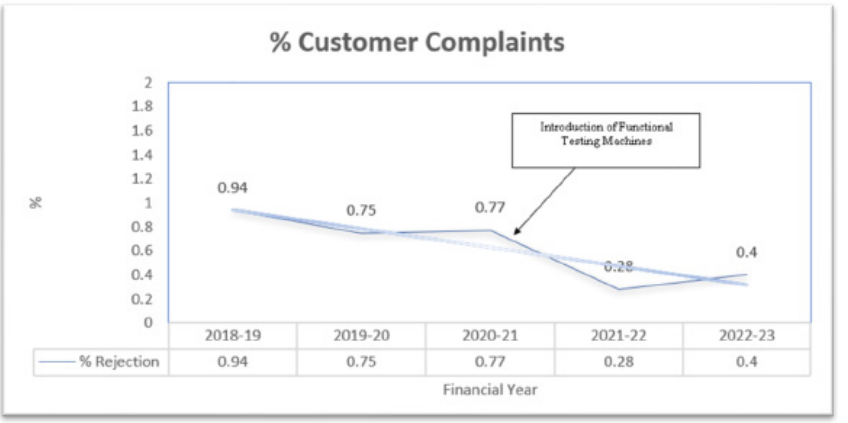


Figure 26: % Customer Complaint, Yearly Trend

SUMMARY

Today's businesses develop and adopt agile processes to achieve quality product in less time. But the quality of the product depends on its proper performance, which can be ensured by end-to-end performance testing. This type of testing helps businesses in many ways, such as improving product performance, improving customer experience, and saving costs. Thus, Sunjewels use the functional testing for providing high-quality product in lesser time. Below are the few points mentioned.

1. Helps to improve the quality of products.
2. Customer satisfaction.
3. Helps to ensure the effectiveness and efficiency of the products.
4. Sunjewels ensures product safety.
5. Helps us to manufacture fully functional flawless products to deliver to our customers.

Sunjewels assures the functionality / mechanism / quality of product by testing with these machines and demonstrated these machines in front of customers during their visits which they greatly appreciated.

During the customer visits, many positive responses and suggestions have been forthcoming regarding our machines.

Figure 27: Functional Testing Lab

CONCLUSION

The purpose of automated systems is to perform functions more efficiently, reliably and accurately than human operators. Manual Functional Testing has its own challenges of maintaining consistent input parameters, where the product is subjected to specific accelerated testing scenarios ranging from 700 ~ 1,500 cycles considering product life cycle of minimum two years. Development of special purpose functional testing machines have boosted customer confidence in reliability and durability of the products manufactured by Sunjewels.

WAY FORWARD

The organization has moved away from reactive approach of testing based on customer feedback. A kick-off meeting is conducted at the start of any new project to capture the customer requirements. During this stage, customer specifications are clarified with cross functional teams while the most appropriate manufacturing processes are identified.

As a proactive approach to improve on product quality, Sunjewels started identifying the alloys and mechanisms involved in the product while defining the internal testing requirement as part of Product Manufacturing Process for special products. The horizontal deployment benefits the improvement in quality parameters across the product categories.

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REFERENCES

- Rocha, Hugo Tiago, et al. "Analysis and Improvement of Processes in the Jewelry Industry." Procedia Manufacturing, vol. 17, Elsevier BV, 2018, pp. 640–46. Crossref, https://doi.org/10.1016/j.promfg.2018.10.110.
- Belapurkar, P. D. "Development and Comparison of Manual Spring Testing Machine With Universal Testing Machine." IOSR Journal of Mechanical and Civil Engineering, vol. 02, no. 02, IOSR Journals, Feb. 2016, pp. 12–16. Crossref, https://doi.org/10.9790/1684-15008020212-16.
- Barash, M. "Automated Inspection/Non-destructive Testing." Journal of Manufacturing Systems, vol. 9, no. 4, Elsevier BV, Jan. 1990, p. 367. Crossref, https://doi.org/10.1016/0278-6125(90)90047-l.

Websites

- https://civilnode.com/download-standard/10641822616592/astm-d5264-standard-practice-for-abrasion-resistance-of-printed-materials-by-the-sutherland-rub-tester.com
- http://gateandupscexammaterials.yolasite.com/resources/standard_books/A%20Textbook%20of%20Machine%20Design%20by%20R.S.KHURMI%20AND%20J.K.GUPTA%20.0001.pdf
- https://www.mecmesin.com/publications/jewellery-testing-tensile-strength-standards-safety-and-durability