



REDESIGN FOR RELIABILITY - WRISTWATCH

M7X01379 Submission – Robert Ogden P140899

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This report is covering the redesign of a wristwatch, specifically the case in order to make the product more reliable and easier to maintain when in service. This will be done by writing a product design specification, to see what the needs of the product are and how these can be met. This will then be followed up by assessing where the design of the watch can fail and cause problems for the user using a failure mode effects analysis. Reliability in a watch means that the watch can be depended on by the user to tell the time accurately at any given time, in any environment.

Product Design Specification:

Customer needs – Redesign for reliability

- Tell the time
- Water resistant
- Comfortable to wear
- Possibly tell the date
- Look good

Quantity –

- Depends on context and price point, 100-1000s

Competition –

- Lots of pre-existing watch brands with heritage and existing models
- Brands and models at every price point from £10-£100,000+

Environment –

- Watch should be usable everywhere; on top of a mountain, in a desert, underwater

Product Cost –

- Intended to cost in the £2000-£3000 range, good mid-range allowing for a high quality product, but not too expensive to be out of the market

Lead times –

- Lead times dependent on components, with not using an in-house movement, development times and costs are reduced
- However custom component production will require time and tooling to be produced

Installation, Maintenance & Repair –

- Tools required for production of the case would be machining tools
- For installation, maintenance and repair of the watch, for example replacement of rubber seals and servicing of the movement, standard watchmaking tools would be required, available at any watchmaker

Intellectual Property –

- Due to the age of the technology, most patents for watches and related developments have expired (for example Rolex helium escape valve and screw down crown patents) aside from those to do with the movements, which because of using an off the shelf movement, is not of concern

Legal & Safety –

- Watches are highly unlikely to cause injury, so any claims are likely to be down to issues with warranty

Budgetary constraints –

- Manufacturing processes such as CNC machining for the production of the case require considerable setup costs, as well as paying suppliers their setup costs for the production of dials and hands

Materials –

- Case will be made from metal, what metal will depend on cost, requirements and aesthetic, however most likely will be produced from

- Sapphire crystal
- Movement
- Dial with luminous indices
- Luminous hands

Ergonomics –

- To be worn on the wrist
- 36mm-40mm case width excluding crown
- Right handed crown, to allow the watch to be worn most comfortably on left wrist
- Possibility to do a variant with left handed crown

Product life and Shelf life –

- Product is intended to last until the rubber seals perish or the movement requires servicing
- Rubber seals are intended to be replaced periodically however most seals last for many years
- Movements require servicing every ~5 years

Processes and Suppliers –

- Cases to be manufactured in house using CNC machining then brushed for surface finish and engraved with a serial number
- Movements to be sourced from specialist movement manufacturer e.g. Swatch Group
- Dials require manufacturing elsewhere, possible to print in house or be sourced printed
- Hands to be sourced from a specialist manufacturer
- Sapphire crystal to be sourced
- Rubber seals to be sourced
- Assembly to be carried out in house
- Testing to be carried out in house (timing and water resistance)

Product disposal and Sustainability –

- Product is not designed to be disposable
- Designed to be maintained and serviced over many years
- At end of serviceable life, depending on failure mode, components could be removed and used in other watches, particularly as the movement is likely to be a generic movement

Product Dimensions –

- 36mm-40mm across the case, optimum size for men, 36mm+ is considered small in a contemporary watch, 40mm- is often considered too large
- 10mm-13mm case height – affords space for the movement yet can fit under a shirt cuff

Performance –

- Timing accuracy to COSC standards (between -4/+6 seconds per day), tested when the watch is assembled
- Water resistant to an equivalent pressure of 200m to allow for swimming and sub-aqua activities (ISO 6425)

Testing in manufacturing cycle –

- Movements arrive pre-tested but are re-tested once assembled
- Defective dials will become apparent when mated to the movement
- Defective hands will also become apparent when mated to the movement
- Cases are inspected visually when manufactured and again when brushed to ensure they fit their requirements

Documentation –

- Serial number on case, numbers come numbered, documented case and movement numbers, to be provided to customer and logged by manufacturer.
- Operation guide to be provided with the watch to ensure risk of damage is minimised

PDS Points of note for redesign for reliability:

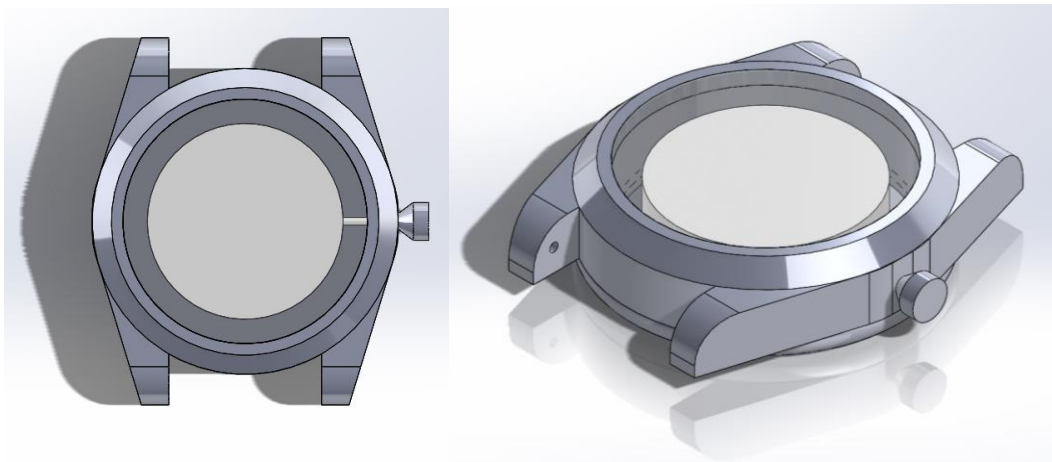
Timing accuracy to COSC standards – needs to be within COSC standards in order to provide consistently reliable timekeeping to the user

Water resistance – needs to be able to be used anywhere, so water resistance is critical to the watch being able to be used in aquatic or even just wet environments e.g. car washing, washing hands

Movement – must be able to handle being used roughly, due to varied environment of use

Original Design:

From the detailing on the product design specification, an initial design for the product could be developed, such that then an FMEA could be performed on this design.



Failure Mode Effects Analysis:

As part of the design process, a failure mode effects analysis can be performed in order to assess the possibilities for failure within the product and the effects these can have on the consumer in order to try and develop actions to minimise these risks. Being what it is, the failure of a wristwatch is unlikely to cause harm or injury to the user and so therefore the severity scores are scaled to take this into account, with the severity score of 10 meaning a catastrophic failure of the watch, resulting in the complete loss of the product. The occurrence score attempts to quantify how likely the failure mechanism is to occur, with 1 being almost impossible and 10 being a certainty that the failure will occur. Detection scores give an idea of whether the failure will be noticed, with 1 meaning that it would be easily observed and 10 meaning that the failure would be impossible to notice. The product of the severity, occurrence and detection scores gives the risk priority number, which gives an indication as to which of the problems are most critical, with the aim of the FMEA being to highlight these issues in order to take action to minimise these risks.

Component	Potential Failure Mode	Potential Effect(s) of Failure	S e v	Potential Cause(s) / Mechanism(s) of Failure	O c c u r	Current Process Controls	D e t e c	R P N	Recommend ended Action(s)	Action Results				
										Actions Taken	S e v	O c c	D e t	R P N
Crown	Water ingress	Damage to movement, dial and hands	8	Crown not secured	3	In owners manual to always secure crown, visual check	4	96	Introduce a screw down crown, makes it visually easier to spot the crown being unsecured and adds extra hermiticity	Introduced screw down crown	8	1	1	8
			8	Water pressure too high	3	In owners manual, as to what is a safe activity with the watch	1	24	Screw down crown. Pressure testing once assembled to ensure each piece meets required specification	Pressure testing introduced	8	2	1	16
			8	Worn/perrished seals	8	Replace seals periodically when the movement is serviced	8	512	Introduce seals made of longer life rubber	Longer life seals introduced	8	5	8	320
	Crown shear	Damage to movement, potentially leading to water ingress	6	Hitting crown on object	2	None in place	1	12	Introduce 'crown guards' to protect the crown from being hit, also a screw down crown adds an extra bit of protection	Crown guards integrated into case design	6	1	1	6
Caseback	Water ingress	Damage to movement, dial and hands	8	Caseback not secured	1	None in place	1	8	Introduce screw in caseback. Pressure testing once assembled to ensure each piece meets required specification, else a loose caseback may escape detection until submerged	Screw in caseback introduced. Each piece pressure tested following assembly	8	1	1	8
			8	Water pressure too high	1	In owners manual, as to what is a safe activity with the watch	1	8	Screw in caseback unlikely to be overcome before crown	Each piece pressure tested following assembly	8	1	1	8
			8	Worn/perrished seals	2	Replace seals periodically when the movement is serviced	8	128	Introduce seals made of longer life rubber, however point from above unlikely to be an issue	Longer life seals introduced	8	1	1	8

Crystal	Water ingress	Damage to movement, dial and hands	8	Impact	1	Crystal protected by bezel, sapphire crystal has high hardness and strength	1	8	Damage to crystal unavoidable in certain methods of impact	No Action	8	1	1	8
Movement	Shock damage	Loss of timekeeping, damage to movement	6	Impact	2	Sourced movement contains shock protection	3	36	Source a movement with a freesprung balance and full balance bridge	Movement sourced with freesprung balance and full balance bridge	6	1	3	18
	Magnetism	Loss of timekeeping	1	Interference of strong magnetic fields	4	User manual recommends the avoidance of strong magnetic fields	2	8	Source a movement with an antimagnetic protection or a-magnetic hairspring	Movement sourced with amagnetic hairspring	1	2	2	4
	Wear damage	Loss of timekeeping, damage to movement	7	General wear over time	6	User manual recommends servicing of the movement every ~5 years	8	336	Being a mechanical movement, not a lot can be done about wear on moving parts, however sourcing a movement with things such as higher jewel numbers or lower friction bearings	Movement sourced with higher jewel number	7	4	8	224
Case	Case damage	Loss of timekeeping	10	Impact	1	Case manufactured from single billet of material	1	10	Unable to improve lack of risk from impact	No Action	10	1	1	10
		complete failure of product	10	Corrosion	1	Recommend avoidance of strong corrosive substances	1	10	Manufacture case from a more highly corrosion resistant alloy	Case manufactured from 904L steel	10	1	1	10

Crown:

The first part of the FMEA is on the crown, with water ingress being the first mode of failure, this was assigned a severity score of 8. This is high due to the effects of water entering the case of the watch would cause water damage to the printing of the dial and the hands. The severity score of 8 is justified by the fact that water would also most critically damage the movement inside the case. This is due to the water mixing with the oils used to lubricate the bearings and moving parts within the movement as well as reacting with the small parts inside the movement which can cause rapid rusting, particularly in saltwater environments, the latter part in particular can necessitate the whole movement being disassembled and cleaned or replaced entirely which when the movement forms a large part of the cost of the product, is a large expense. There are several potential causes for the water ingress from the crown, the one with the highest risk priority number is due to worn or perished seals. This is due to the occurrence and detection values both being 8. The occurrence value of 8 is due to the fact that with the seals being made of rubber, it is inevitable that over time the rubber will degrade, thus leading to the loss of a strong seal within the crown. The detection score of 8 is due to it being impossible to check the condition of rubber seal without removing the crown and stem from the watch and visually inspecting. In order to try and combat this issue, the current control for this is that when the watch movement is serviced the rubber seals are replaced with new ones, however an action which could be taken to try and combat this issue would be to replace the seals with seals made of a longer lasting rubber which would take longer to break down. The mechanism of failure with the second highest RPN (of 96) is the crown not being secured as with the crown not being in the fully down position water can enter the case through the gap left. This mechanism has an occurrence score of 3 and a detection score of 4, the low occurrence score is due to the current process control which is that in the owner's manual it is stated that the crown should always be secured and so when the product is in use then the crown should be secured. However the detection score of 4 is due to if the user forgets to secure the crown immediately, it could possibly be very difficult to visually detect that the crown is not in its secured position. The possible action to combat this is to introduce a screw down crown to the case, this makes it more easily visually detectable that the crown is unsecured, but also makes it more of a conscious effort to re-secure the crown in the fully down position, meaning the user is less likely to forget. Adding in a screw down crown also adds an extra portion of hermiticity to the case. The final method of failure is assigned to the water pressure being too high and overcoming the seals, this has an RPN value of 24, with occurrence and detection being assigned scores of 3 and 1 respectively. The occurrence value is due to it being possible for the user to exceed the water resistance of the case, with actions such as swimming creating high concentrations of pressure around the crown, thus being able to exceed the pressure of the seals. The detection score is high due to it being quite obvious that the seals have been exceeded due to moisture being inside the case, however this is too late to prevent damage to the watch. The current control to prevent this is that in the owner's manual it states what is a safe aquatic activity to do whilst wearing the watch. Possible actions to reduce the risk involve pressure testing each watch to ensure each piece meets a required specification, a screw down crown would also help to prevent this by increasing the pressure necessary to overcome the seals within the case. The final failure mode of the product involving the crown is a crown shear, the forcible removal or damage of the crown possibly by hitting the crown on an object, possibly leading to damage to the movement and water ingress if the crown is sheared whilst submerged. RPN for this method is 12, consisting of a severity of 6 due to the potentially severe consequences for the product, but an occurrence of 2 and detection of 1, due to it taking a considerable force in a particular way to shear the crown from the watch and the detection score due to with the considerable force, it is a noticeable problem. There are no controls currently in place, however the introduction of crown

guards to the case, can help protect the crown from being hit and the screw down crown introduced to prevent the ingress of water also helps to protect the crown from shearing by effectively attaching it to the case.

Caseback:

The next component considered in the failure mode effects analysis was the caseback, the back section of the case which secures the movement into the case. The potential issues and mechanisms for failure with the caseback are largely the same as those for the crown, being water ingress, giving a severity score of 8, with worn or perished seals being assigned the largest RPN number of 128. This is again currently controlled by replacing the seals when the movement is serviced and can be further improved by using seals made from longer life rubber. The next method of failure is the caseback not being secured, with a risk priority number of 8, due to the occurrence being 1 and the detection being 1 as the caseback not being secured is something which would be hard to not detect visually or would be evident when the watch is worn. There are no controls currently in place to prevent this, however the introduction of a screw in caseback which must be tightened to a set torque before being pressure tested when the product is fully assembled should make this even less of a problem. The final failure mode for the caseback is the water pressure being too high, however this is less of an issue than the pressure on the crown as the caseback is somewhat more protected from the pressure of the water, however the control is the same, in that the owner's manual states what is a safe activity with the watch.

Crystal:

Another component which can fail is the crystal, the clear substance covering the dial. The only mechanism by which the crystal can fail is impact, be that direct or transferred through the case, for example if the watch is dropped. The severity score for this is 8 due to the high severity of damage to the crystal, due to the nature of how a sapphire crystal breaks, it is one of the only ways in which the watch could potentially harm the user, as the crystal shatters into potentially harmful shards. If the user is unharmed however it is still an extremely serious issue as the watch is open to ingress of water and other debris, including the shards of crystal themselves, potentially causing damage to the movement dial and hands. The controls for preventing damage to the crystal are largely passive and involve the bezel protecting the crystal from direct impacts, however it is largely impractical to fully protect the crystal without resorting to unnecessary expense and the loss of aesthetic quality and so no further actions could be taken.

Movement:

There is also potential for failure within the movement of the watch and the failure mode with the highest RPN of 336 is wear damage. Being a mechanical device, general wear to the moving parts within the movement is inevitable over time, however the reason it scores so highly is that there will be a loss in timekeeping ability and if left unchecked the damage to the movement can be serious and require expensive repairs or complete replacement of the movement, therefore it was assigned a severity score of 7. The inevitability of wear on the parts means that the occurrence score is 6, this is only 6 due to the variance in how much the parts would wear given varied amounts of usage the product is likely to see between users. The detection score is high at 8 as unless the user removes the caseback and is qualified to inspect a watch movement, they are therefore unlikely to know

whether there is a problem until they hear noises such as grinding or clicking from the movement. The current control to prevent wear in the movement is that the user manual recommends the servicing of the movement every 5 years, to replenish the oils, replace bearings and clean any debris from within the movement. Being a mechanical movement, not a lot can be done about wear on moving parts, however one potential action which could be taken is to source a movement with a higher jewel number to prevent some wear or to source a movement with lower friction bearings. Shock is another means by which the movement can be damaged, by being dropped or through impact. This can cause a loss of timekeeping performance or damage to fragile components, potentially requiring expensive professional intervention or replacement, therefore the severity score is set at 6. The occurrence is set at 2 and the detection at 3, this is due to it being possible but unlikely that the watch will experience such an impact and if there is an issue the user is likely to notice upon looking at the watch following the impact, however a simple loss in timekeeping performance may not be noticed. The risks of damage to the movement through impact can however be minimised by sourcing a movement with a freesprung balance assembly and a full balance bridge, which protects the main source of damage and loss of timekeeping performance from impact damage. Although technically not a failure in the strictest sense, magnetism can cause a loss of timekeeping performance, making the coils of the mainspring stick together, making the watch run very fast which can be problematic. The severity of this issue is only 1 as the watch can easily be demagnetised, it is more of an inconvenience to the user. The occurrence is set as 4 as the watch mainspring is only ~0.2mm thick, meaning that depending on where it is used, it could be magnetised by things such as the magnets in laptop or phone speakers if the watch is in proximity to these things. Detection is set at 2 as it is easily noticeable that the watch is running several minutes fast every day. Current control is that the user manual recommends the avoidance of strong magnetic fields, however a potential action to prevent the magnetism would be to source a movement with antimagnetic protection or an amagnetic hairspring.

Case:

The final component which could be a source of failure is the case itself, primarily through impact or corrosion, both with an RPN of 10. Impact or corrosion could cause damage to the case of the watch, which could lead to a complete failure of the product, requiring the entire watch to be replaced, leading to a severity score of 10. It is however extremely unlikely that this would happen as in the case of impact, it is far more likely that the crystal or movement would be damaged beyond repair long before the case, and in the case of corrosion it is unlikely that the watch would be exposed to such environments for a long enough period of time for this to be an issue, therefore both mechanisms have an occurrence score of just 1. They also both have a detection score of 1 as it is likely that such catastrophic problem would be immediately noticeable. The only possible action to remedy this would be to manufacture the case from a more corrosion resistant material or add a coating to the case.

Actions:

Crown:

In order to prevent the ingress of water through the crown, a screw down crown was introduced to the design. This has the advantages of it being more visually noticeable that the crown is not in its fully down position, as well as making the watch itself more resistant to water pressure when compared to a simple push down crown. The screw down crown also has the advantage of adding a bit more protection from shearing due to impact due to the crown being screwed onto the case as opposed to merely sitting against it. This is more difficult and expensive to manufacture, due to

having to machine a threaded part on the side of the case for the crown to attach to as well as having to tap the inside of the crown to screw onto the case, however this is offset by the advantages afforded the product. It was decided to introduce crown guards to the case also as although they require additional machining and affect the aesthetic quality of the design, they minimise the risk of damage from striking the crown.

Caseback:

In a similar way to the screw down crown was adopted, the screw in caseback was introduced. Again although the introduction of the screw in caseback will cost more due to additional manufacturing, when paired with a screw down crown they effectively seal the watch, meaning that the problem of water ingress is extremely unlikely unless the crown is left out or there is an issue with the rubber gaskets.

Movement:

In order to add additional protection to the movement from both impact and magnetism, it was decided to source a highly jewelled movement with a freesprung balance, full balance bridge and amagnetic silicon hairspring. Although doing this increases the cost of the sourced movement, it means that the movement is more likely to last for long periods of time without issue, reducing the number of warranty issues having to be dealt with due to problems with the movement.

Case:

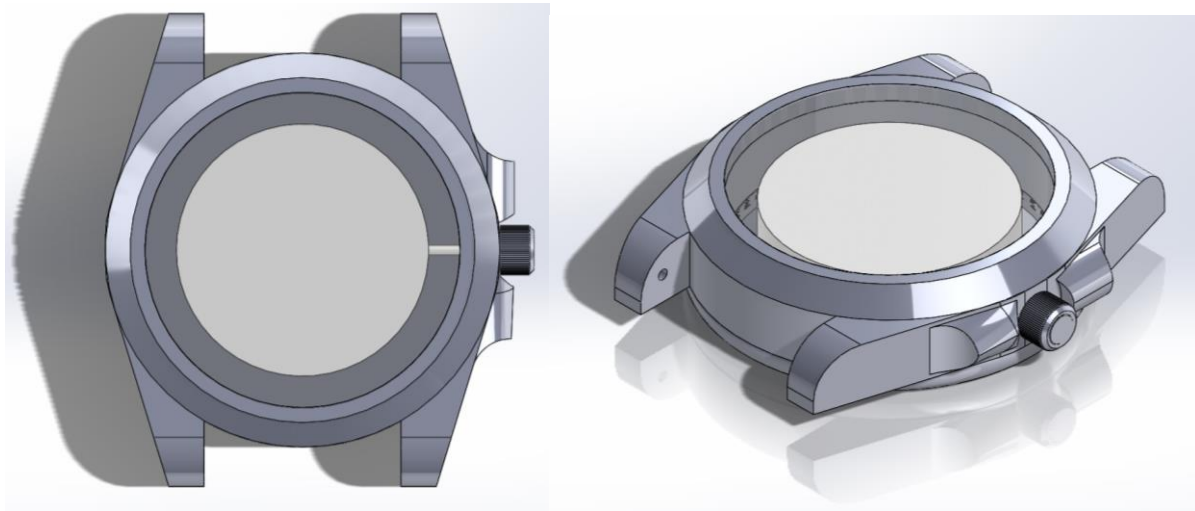
The final specific change to the design was to manufacture the watch case itself from 904L stainless steel. This has the advantage of being more resistant to corrosion due to 904L stainless steel having a higher chromium content than most stainless steel alloys, approximately 19-23% chromium by weight, whilst also being a slightly softer metal and so easier to machine.

System:

Longer life rubber seal gaskets were adopted in order to provide additional security against the perishing of the seals over time, which although inevitable, is best to prevent for as long as possible and the longer life gaskets are unlikely to add any noticeable expense to the production process. Dry pressure testing after assembly was also introduced, this allows each individual product to be tested to ensure that there is a good seal protecting the movement from water. Dry pressure testing was selected over immersion testing due to it then being possible to replace seals in or reassemble any defective pieces as opposed to causing permanent and costly damage in an immersion test.

Final design:

Integrating the design changes detailed in the action section of the FMEA, the finished design appears as follows.



Sources:

Seiko Corporation, SRP779K1 user's manual, 2016

Omega, Seamaster 300m 212.30.41.20.01.003 Operating Instructions, 2017

International Organisation for Standardisation, ISO 6425:1996

(<https://www.iso.org/standard/12774.html>)

Controle Officiel Suisse des Chronometres, (<https://www.cosc.swiss/en/certification>)