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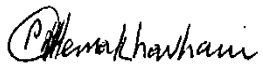

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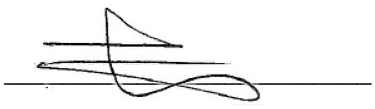

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1. Background

Eskom is faced with the ailing fleet of power stations which requires extensive and innovative maintenance. This, in turn, requires advanced repair methods, like robotic welding, to build-up the Rotor journals, casing's locating landings, valves locating landings and other related components, to design sizes.

Eskom Rotor journals (Kriel, Duvha, Majuba, and Tutuka LP's) were previously machined to correct mechanical damage (grooves) and wearing that had occurred during operations. Machining of these journals resulted in sub-standard journals, and thereby limiting the interchangeability of the rotor within the same fleet. Therefore, the solution to this problem is to weld build the journals to design sizes.

With the number of skilled welders decreasing and the job being extensive and rather dangerous, implementing a robotic welding system is foreseen as the next step for Rotek to adopt to fix journals and locating landings.

2. Discussions

ERI TGS Works is a Manufacturing and Refurbishment workshop for all Eskom Power Stations, and non-Eskom Power Stations. Works contains Welding shop, Machine Shop, Balancing shop, Bearing shop, Blading shop and Fitting shop.

According to the predictive analysis, 20% of all work carried out at Works involves welding during the refurbishment of spares. Eskom Rotor journals (Kriel, Duvha, Majuba, and Tutuka LP's) are machined to correct mechanical damage (grooves) and wearing that had occurred during operations.

Machining of these journals resulted in sub-standard journals, and thereby limiting the interchangeability of the rotor within the same fleet. The temporary solution identified was to rely on sub-contractors entirely, to laser weld build-up the journals, whenever the need arises. The cost of laser welding one journal is around R550 000 to R900 000. If a need arises to weld all the above-mentioned rotors, the laser welding cost will amount to R40 000 000. ERI have been, previously, requested to oversee journal laser welding, at least 2 rotors per year. Therefore, the proposed permanent solution to correct the journals is by welding using Robotic Welding Machine.

A basic robotic welding system is formed by two subsystems: the welding equipment delivering the energy from the welding power source to the workpiece, and the robot providing relative

positioning of the heat source and the workpiece. Normally six-axis industrial robots comprising a three-axis lower arm and a three-axis wrist are used, since they enable the welding torch mounted at the wrist to achieve all the positions necessary for three-dimensional welding.

Humans are not completely removed from the usage of robotic welding systems. To use a robotic welding unit, programs are inputted via the teach pendant and saved to the controller, telling the robot what to do. These programs move the welding robot and dictate the movement of the torch on the end of its arm, placing it exactly where it needs to perform tasks. Robotic welding needs to be supervised constantly and maintained by a trained operator or someone certified for this skill.

The rotor will have to be coupled to a rotating table and secured on the rollers to aid with the rotation during welding. The robot is programmed to follow a certain path to weld. A short calibration (integration) of the rotating rotor and the robot is performed. Welding commenced when the electrode reaches the required position. Then the welding head travels along the programmed pathway resulting in neatly welded seams.

3. Specifications.

3.1.Robotic Welding System:

The specifications of the Robotic Welding System are on Table 3 below:

Table 3: Robotic Welding System Specifications.

Robotic Welding System (Machine)			
Machine Description	*Quantity*	*Machine Specifications*	
Industrial Arc Welding Robot	One	**Payload**	8 kg
		Mounting	Mobile base
		Robot mass	±150 Kg
		Axes	Six
		Reach	2 000 mm
		Velocity	Up to 5m/s
		Acceleration	Up to 25m/s2
		Repeatability	≥0.05 mm
		Communications	Profibus, DeviceNet, CANopen, Ethernet/IP and serial channels
		IO capabilities	Digital/analogue IOs
		Welding Arm	Through Arm
Power Source	One	**Robotic Power Source**	Processes: MMA, TIG, Pulsed TIG, MIG, Pulsed MIG, Advanced Process, FCAW, Surface Tension Transfer
		Rated Output	570A/40V/60%
		Maximum OCV	75VDC
		Input Current @ rated output	50Hz: 63A
		Out Put range	5 – 570A, 5-325 A on STT
		DC Voltage Range	5 - 55 V on Pulse
		Pulse Frequency	0.15 - 1000 Hz

		Applications	For welding thicker materials in robotics, hard automation and semiautomatic applications.
		Features	• STT DC CC CV • Surface Tension Transfer (STT) Process • Digital Communications Technology • Waveform Control Technology • Patented Pulse-On-Pulse, Power Mode Processes
Wire Feed	One	**Wire Drive System**	Digitally controlled wire drive
Process Sensors		**Weaving Function**	
		Overlap function	
		Arc Start entry	
		Welding Current Measurement	Hall effect sensor Current shunt
		Arc Length Control	Voltage sensor
		Distance Control	Capacitive Sensor
		Weld Edge Searching	Proximity sensor
		Weld Seam Tracking	Through Arc sensing
		Weld Pool monitoring	Vision sensor
Welding Cell	One	**Base Frame**	Aluminium
		Total Size (LxW)	± 12 000 x 6 000 mm
		Application	Arc Welding
Welding Torch	Two	**Welding Process**	TIG
		Torch Type	TOPTIG Torch
		Maximum Intensity	500A with DC – 100% Cycle 400A with AC – 100% Cycle
		Arcing	High Frequency
		Cooling	Water Cooled
		Electrode	Diameter: 1.6 – 6.4 mm
		Gas	Gas flow: 4 – 12 L/min
Positioner	Two	**Axis**	Two
		Payload	400 Kg
		Standard Turning Range	Infinite
		Standard Tilting Range	90^0
		Loading Height	±800 mm
		Rated Welding Current	430 A (100% Duty)
Heavy Duty Rotary Table	One	**Face Plate**	2500 mm
		Centre Height in Vertical	2625 mm
		Minimum Increment	0.001^0
		Working load	25 000 Kg
		Clamping Torque	12 000 Kgf.m
		Maximum Rotation Speed	2.7 RPM
		Driving Torque	875 Kgf.m

Training	11 Welding Personnel	**Robot Training**	• Power up / power down
			• Recall teach pendant, control panel keys & switch functions
			• Select operate and teach using the control panel & teach pendant
			• Perform tool alignment
			• Move robot axis using various coordinate systems
			• Program Teaching
			  o Linear Program
			  o Circular Program
			  o Linear Weave Program
			  o Circular Weave Program
			• Program Modification
			  o Linear Program
			  o Circular Program
			  o Linear Weave Program
			Circular Weave Program Operation
			• Linear Program
			• Circular Program
			• Linear Weave Program
			• Circular Weave Program

		Integration	• Modify an existing welding program and correct errors • Use selected edit functions • Write a job using sequence commands • Modify a job • Operate a job using control panel and teach pendant • Recall system set / advanced functions using teach pendant • Recall system data using teach pendant • Use upload / download software • Teach weld program • Modify weld program using override function • How to change batteries
Robot Repairs and Maintenance Program			***The Robot Arm:*** • Remove all previous integration wires and components • Check all robot connections • Inspect arm for any stress cracks or abnormalities • Check/Repair/Replace Servos, Harmonics, and Reducers • Ensure Robot Functionality and Performance • Replace all grease in robot • Inspect robot for any grease or oil leaks • Clean robot arm and strip old paint • Repaint robot arm to factory color ***The Controller:*** • Clean robot controller and strip old paint • Check controller for any damage • Inspect all components for functionality and performance • Verify incoming voltage • Repaint controller to factory colors ***Teach Pendant:*** • Check, Repair, Rebuild Teach Pendant

			• Ensure all buttons, lights, and switches are functioning properly
Warranty	3 Years		

3.2. Robotic Welding Cell:

One of the challenges of planning a new welding automation project is visualizing the equipment layout. There are many configuration options from which to choose from. What is highly efficient in one facility might not be efficient in another production facility. It all comes down to our goals and the details of our refurbishment process.

In many cases one have a choice between what is sometimes called commercial-off-the-shelf (COTS), pre-engineered, or custom-built systems. Budgetary and production goals are a big part of this decision. COTS systems are generally a standard package which includes the structure/work cell frame, robot, gun, safety equipment, and part positioning mechanisms (turntables, trunnions, etc.).

Custom systems often maximize flexibility of the footprint, shape of the weld cell, and the part sizes and operations it can accommodate. With a custom system, it may even be possible to integrate welding with other tasks that come before and after. Some examples are: Adding a second robotic arm. A custom system can also be designed with extra space or an expandable structure/frame that can be modified for a larger quantity or different-shaped parts in the future.

Considering the Works layout, custom built system will be suitable for the welding repairs that Works undertakes. The custom-built welding cell must be able to accommodate the welding of GEC LP Rotors. The ideal dimensions of the welding cell are 6 000 mm width x 12 000 mm length. As such, the recommended floor space identified is located on 75 Ton Aisle, adjacent to the hot box area.

3.3. Training of Personnel:

Eleven (11) Welding personnel that includes 8 Welders, Welding Supervisor, Welding Technician and Welding Engineer have been identified to undergo the necessary training to operate and maintain the Robotic System. Training will be divided into two modules:

i. Robot training and integration: This module will be offered by the supplier for the system. The suppliers normally offer training to 3 personnel, and it takes at most, 5 days. The training includes basic robot training and integration.

ii. Advanced Robot training: This module will be offered by the independent supplier. It includes programming, coordinate systems, peripheral device and end effector control. It also includes basic maintenance procedures like backing up the controller or restore a previously saved backup, and collaboration capabilities.

4. Cost estimates of Robotic Welding System

a) This new budget for Robotic Welding System has not been planned and approved for the CAPEX spend for this financial year of 2022.

b) Therefore, in addition to the CAPEX budget allocated for 2022 financial year, an additional R 12 million should be allocated for the Robotic Welding System (see table 6 for cost of Robotic welding system).

Table 6: Robotic Welding System Budget Cost

Machine Description	Machine Type	QTY Required	Price per machine	Total Price	Price inclusion
Arc Welding Robot	6-Axis	2	R 889 900.00	R 1 779 800.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Power Source	Robotic Power Source	2	R 309 900.00	R 619 800.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Wire Feeder	Wire Drive System	2	R 57 000.00	R 114 000.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.

Process Sensor	Weaving Function System	2	R8 000	R16 000	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Process Sensor	Overlap Function System	2	R7 000	R14 000	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Process Sensor	Welding Current Measurement System	2	R2 000	R4 000	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Welding Torch	TOPTIG	2	R15 000.00	R30 000.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Welding Positioner	2-Axis	2	R1 300 000.00	R2 600 000.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Heavy Duty Rotary Table		1	R3 200 000.00	R3 200 000.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.

Welding Cell	Aluminium Frame	1	R 809 000.00	R 809 000.00	1) Delivery to ERI works. 2) Installation at ERI premises. 3) Commissioning. 4) Training of 3 Personnel. 5) Supplier to supply electrical and pneumatic connections.
Robotic Training	• Upgrade KR C4 • Robot Operation Pro • Programming 1 KR C4	11	R 50 450.95	R 561 000.00	1)Training offered at Works Premises.
			TOTAL	**R9 747 600.00**	
			20% Contingency	**R1 949 520.00**	
			Total Including 20% Contingency	**R 11 697 120.00**	

5. Conclusion

In conclusion, the welding robot is fast, accurate, productive, cost- effective and safe to use. It reduces delivery times, ensures high quality and better efficiency of the welding process itself, making it possible to weld products at lower prices.

Procurement of Robotic Welding System will enable Welding shop to weld repair huge and complex components that requires extensive and innovative welding process. It enables Works Welding shop to produce high-quality welds in a shorter cycle time, and to overcome technical difficulties and expand their capability.

Robotic welding saves a lot of valuable time because the work is automated and much faster. Therefore, the robotic welding system ensures a significant increase in production with accuracy.