RECOMMENDED TECHNICAL SPECIFICATIONS FOR PROCUREMENT OF SYSTEMS FOR A CLEANING AND DEBURRING WORKSTATION

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Certain commercial equipment is identified in this paper to adequately describe the systems under development. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment is necessarily the best available for the purpose.

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I. INTRODUCTION

This manual provides the technical specifications for the Cleaning and Deburring Workstation (CDWS). These specifications cover the Workstation Controller, the Deburring System, and the Part Handling and Cleaning System. Pertinent references for the Cleaning and Deburring Workstation are listed in the final section.

1. SYSTEM DESCRIPTION

The Cleaning and Deburring Workstation is one of six workstations at the Automated Manufacturing Research Facility (AMRF) of the National Institute of Standards and Technology (NIST). The CDWS cleans and deburrs the metal parts produced by the machining workstations of the AMRF. Equipment at the workstation includes a six-axis electric robot for deburring, a five-axis hydraulic robot for part handling and buffing, a washer/dryer and buffing system for cleaning and polishing, a rotary vise for clamping parts, and two roller tray stations for transferring parts.

The machined parts enter and exit the workstation on part trays placed at the roller tray stations. The part handling robot, under command of the Workstation Controller (WSC), grasps and carries a part either to the rotary vise or to the washer/dryer system. Normally, parts first undergo deburring, so the part handling robot puts the part in the vise where it is clamped. The deburring robot moves to the vise and begins to deburr the edges on the top side of the part, changing its deburring tool as required. If necessary, the part handling robot reorients the part, and the deburring robot deburrs the edges of the newly exposed face. If a part is to be cleaned, the part handling robot places it on the washer/dryer index table. From here, the part cycles through the washer, where a hot spray removes cutting fluid, deburring dust, and buffing compound. Once washed, the part is indexed into the dryer, where hot air dries the residual water. When all cleaning and deburring processes are completed, the part handling robot transfers the part back to the tray station.

Process planning and task scheduling are undertaken by the WSC. The WSC is a set of software routines running on a SUN computer. The WSC provides a graphic interface for user selection of finishing processes and parameters, a scheduler which allocates tasks at runtime, interfaces to the equipment level, and an interface to the AMRF cell and database.

2. PURPOSE OF THIS MANUAL

The purpose of this manual is to provide recommended technical specifications for the CDWS. These specifications should prove useful to researchers developing a system modeled after this facility. These specifications are functional only; that is, they do not list the manufacturers of equipment used in the CDWS, but only describe the function and capabilities of the various systems.

3. HOW THIS MANUAL IS ORGANIZED

This manual is divided into five parts. The Introduction gives a brief overview of the CDWS and explains the purpose and organization of the manual. Section II provides technical specifications for the workstation controller. Section III provides the specifications for the deburring system. Section IV provides technical information for the part handling and cleaning system. A list of pertinent references is provided in Section V.

4. WHO SHOULD USE THIS MANUAL

This manual is intended as a guide for researchers who need to specify and procure automated manufacturing equipment computer hardware and software for a cleaning and deburring research facility.

II. WORKSTATION CONTROLLER

The Workstation Controller is a set of software modules that comprise a graphics interface for process plan generation, a robot pose generator, and a task scheduler. The WSC communicates via an ethernet network to the higher levels of the AMRF, and to the workstation equipment levels via serial RS-232 connections.

Typically, a CAD model of a part is developed before the part is to be deburred. This model is used to generate a picture of the part on a graphics screen. A user then uses a mouse to select edges to be deburred, the tools which are to be used, and the tool parameters such as speed and feed rate. Additionally, the user selects part handling and fixturing data by using the mouse to manipulate the part relative to drawings of the vise and robot gripper. Once this process plan is created, a trajectory generator automatically computes robot locations based on the desired deburring, part handling, and fixturing locations. Once the set of robot locations has been computed, the WSC schedules the various part handling, cleaning, and deburring tasks at runtime based on the availability of resources and the capabilities of each robot.

1. RECOMMENDED COMPUTER HARDWARE

The computer platform for the WSC must provide a graphics interface to allow for the graphic development of the process plan. The display must be of sufficient resolution to depict accurately the part geometry, and requires only monochrome capability. Additionally, the computer must support both a keyboard and a mouse for data input, the former for programming and the latter for edge and fixturing selection when running the process planning software.

The computer hardware should include at least 4 megabytes of RAM, and at least 130 megabytes of hard disk storage. Additionally, a facility for backing up the contents of the disk to tape should be provided. This can include either reel-type or cassette media.

Communications support for both a local-area network (such as Ethernet) and multiple serial channels must be provided. The local-area network is used for communication between the WSC, the factory cell controller, and the database. The serial channels are employed for communication between the WSC and the workstation subsystems: robots and equipment controllers.

2. RECOMMENDED SOFTWARE

The WSC has been implemented in a multitasking environment. This allows for tasks to be spawned independently and executed on a time-shared basis. The operating system must therefore be chosen to support multitasking, and the programming languages selected must allow for calls to the operating system.

The WSC has been coded using both the C and LISP programming languages. Although other languages may be suitable, there are several desirable features that should be supported by the language or languages chosen. These include compilability for speed of execution, an interface to the operating system, and graphics support. Furthermore, the languages should provide the instructions necessary to allow for vector and matrix manipulation, and list processing.

III. DEBURRING SYSTEM

Deburring is performed by a six-axis electric robot, which applies tools to the edges of machined parts. The robot is fitted with a quick change wrist to allow for the selection of various pneumatic tools or a gripper. A wrist force sensor provides force feedback, which is used to compensate for inaccuracies. The robot is controlled using the NIST-developed Real-Time Control System (RCS), interfaced to the vendor-supplied controller according to a slave protocol.

1. RECOMMENDED ROBOTIC EQUIPMENT

Robotic deburring is typically a light-payload, high-dexterity process during which a robot applies various deburring tools to the features of a part which are to be finished. The materials deburred in the CDWS are soft metals, such as aluminum and brass, which do not require the use of high-speed tools or hard cutters. These materials are best deburred using soft tooling such as compliant brushes. The automation strategy adopted in the CDWS requires that a single robot perform deburring using several types of these compliant tools, implying the need for an automated tool changing device such as a wrist quick-change.

It is recommended that the robot provide at least five degrees-of-freedom to allow dexterous access to all part features requiring deburring. If a five-axis robot is chosen, care must be taken to insure that the axis of rotation of the deburring tools does not coincide with any of the wrist axes. If a six-axis robot is employed, the degree-of-freedom provided by the rotary tool usually results in redundancy of one of the three wrist axes. This condition is useful in many cases for resolving interference problems between cables, hoses, and brackets on the robot arm, but is not required.

The payload of the robot must be sufficient to support the manipulation of the deburring tools and quick-change hardware, and to insure that desired cutting forces can be attained during deburring. For deburring of aluminum and brass, it is recommended that abrasive-loaded nylon brushes be used. The payload of a typical robot used for “soft” deburring with rotary brushes is on the order of 10 pounds.

The recommended accuracy and repeatability of a deburring robot is difficult to assess, as is the stiffness of the robot arm. For the deburring robot in the CDWS, the repeatability has been rated by the manufacturer as approximately 0.008 inch. Although no figures for the accuracy were provided, it has been estimated by researchers at the workstation that the accuracy is no greater than an inch. Stiffness figures are also difficult to determine, but have been estimated to be approximately 1 pound-foot/mil. These values are sufficient for the robotic deburring of aluminum and brass with soft tooling, using robot trajectories computed off-line from CAD data.

2. RECOMMENDED COMPUTER HARDWARE

The robot is controlled using the NIST-developed Real-Time Control System (RCS). This system implements functions normally performed by the vendor-supplied robot controller, which have been bypassed with the slave protocol. This protocol requires that the user compute and serially download robot joint angles every 28 milliseconds. The slave protocol allows the user a much greater control over the actions of the robot, but at the price of additional user computation.

It is recommended that the calculation of robot joint angles take place in a computing environment structured in the hierarchical RCS methodology, and that the robot controller support the real-time downloading of robot joint angles. The RCS methodology decomposes high-level tasks into a sequence of lower-level tasks. At the highest level, the task is described generically in terms that a human user readily understands. The task is further refined at each level, until at the lowest level the task consists of transmitting joint angles to the robot controller.

The recommended computing configuration to support this real-time hierarchical task decomposition consists of four independent microprocessor-based single-board computers, which communicate across a backplane (see [8]). It is further recommended that each processor operate at a speed of at least 8 megahertz, and include a floating-point coprocessor to increase performance. The computer boards should provide at least 128 kilobytes of RAM. Additionally, 512 kilobytes of backplane or common memory is desirable for interprocessor communication and storage of common data files. Capabilities for serial, digital, and analog input and output must also be supported to allow the computer platform to be interfaced to human operators, sensors, and the robot controller. These additional items may be present on the microcomputer boards, or may be separate boards in the backplane.

Non-volatile storage, in the form of hard disks, floppy disks, and tape, are also required for storage of system programs, user programs, and data. Hard disk storage of 20 megabytes is sufficient for use with a typical RCS; floppy disk or tape backup capacities can be chosen to suit the users.

3. RECOMMENDED SOFTWARE

Because real-time programs will be downloaded to the target computing hardware, the choice of a programming language is dependent upon the hardware selected. Many development systems offer programming environments tailored to hardware configurations that support the RCS methodology. In some cases, the programming language and operating system reside in PROMs that are placed on each target board. A terminal interface allows a programmer to edit, compile, and execute computer code for each board. Alternatively, some development systems require a host computer to support code editing and compilation, then provide a mechanism for downloading this code to the target hardware when it has been finished. Either development system is satisfactory. It is up to the system designer to choose hardware and a compatible software development system which perform at the speeds required for real-time computation, while offering ease-of-use.

IV. PART HANDLING AND CLEANING SYSTEM

The part handling and cleaning system is responsible for bringing incoming parts into the workstation, performing part fixturing for deburring, cleaning processed parts, and placing outgoing parts in the tray stations for delivery. This system consists of a hydraulic robot with the vendor-supplied controller; an NIST-designed rotary vise; a pneumatic gripper; and buffing and cleaning equipment. Control of equipment is performed using an RCS, which communicates between the WSC, the robot controller, and NIST-designed hardware interfaces to the various equipment controllers and actuators.

1. RECOMMENDED ROBOTIC EQUIPMENT

A six-axis robot is recommended for part handling and buffing. Although part handling can be performed with only five axes, proper part orientation at all buffing wheels mandates the availability of six axes. The payload of the robot must be sufficient to support the weight of the gripper and part, and to apply the proper force when buffing. The payload of the robot in the CDWS has been rated as 150 pounds, which has been determined to be more than adequate.

The accuracy of the robot in the CDWS has been increased by error mapping to approximately 0.1 inch in the volume mapped. The repeatability has been determined to be approximately 0.01 inch. These figures have been determined to be sufficient. The pre-mapped accuracy of the robot, however, is much lower than the mapped accuracy; if a robot is selected with lower accuracy, some means must be available in the robot programming language for programming an error map to increase the accuracy.

2. RECOMMENDED BUFFING AND CLEANING EQUIPMENT

The buffing and cleaning equipment is used for polishing and cleaning the parts after deburring. Buffing is accomplished with any of three types of wheels: cloth, abrasive-loaded nylon monofilament brush, or wire brush. The wheels are mounted simultaneously on different sections of a rotating spindle so that the selection of wheel type can be made automatically. The cloth wheels require buffing compound, which is applied with pneumatic compound sprayers. A dust collector is placed behind each buffing area so that buffing debris can be collected with a minimum of cleanup. The buffer allows for a wide range of spindle speeds, so that a variety of finishes can be produced on different metals. Typically, the speeds used range from a few hundred to a few thousand revolutions per minute.

The part cleaner consists of a rotating index table with four quadrants. These quadrants revolve into a washer section, where hot water sprays from above and below remove cutting fluids and buffing compound, and into a dryer section, where hot air is blown onto the part to dry it. The part is then indexed out into one of the exit quadrants, where a robot removes it for placement into the exit tray station. It is recommended that the part cleaner provide some method for restraining the motion of the parts during washing and drying, so that the parts exit in a known location and orientation for robot pickup.

In order for the workstation to be automated fully, the buffing wheels and part cleaner must provide an interface for computer control. It is also desirable for this interface to support manual control, in cases where debugging or testing are to occur. The computer interface will operate under the control of the RCS, as described in the following section.

3. RECOMMENDED COMPUTER HARDWARE

The recommendations for computer hardware are the same as for the deburring system. This recommended computing configuration consists of four independent microprocessor-based single-board computers, which communicate across a backplane (see [8]). It is further recommended that each processor operate at a speed of at least 8 megahertz, and include a floating-point coprocessor to increase performance. The computer boards should provide at least 128 kilobytes of RAM. Additionally, 512 kilobytes of backplane or common memory are desirable for interprocessor communication and storage of common data files. Capabilities for serial, digital, and analog input and output must also be supported to allow the computer platform to be interfaced to human operators, sensors, and the robot controller. These additional items may be present on the microcomputer boards, or may be separate boards in the backplane.

Non-volatile storage, in the form of hard disks, floppy disks, and tape, is also required for storage of system programs, user programs, and data. Hard disk storage of 20 megabytes is sufficient for use with a typical RCS; floppy disk or tape backup capacities can be chosen to suit the users.

4. RECOMMENDED SOFTWARE

The part handling robot is not run under RCS, but uses the vendor-supplied robot control software. However, the RCS programming language, SMACRO, is used to program the computer interfaces to the equipment control computers. These computers actuate the rotary vise, cleaning equipment, and tray station lockout mechanisms. Software considerations identical to those for the deburring system apply also to the part handling and cleaning system.

V. LIST OF REFERENCES

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