TECHNIQUES OF WORKING STAINLESS STEEL IN SECONDARY SCHOOL METAL SHOP

by

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CHAPTER I

INTRODUCTION

Statement of the Problem

The inherent characteristics of stainless steel, an increasingly popular commercial metal, poses a problem of modification and adaptation of industrial practices to the limited facilities of the secondary school metal shop. This experimental research is intended to help solve this problem.

Hypothesis

The addition or inclusion of stainless steel with other materials in use in the school shop is possible and practical. The difficulty of working this tougher material requires care in selection of tools and equipment. The need is for "quality" tools rather than an increase in "quantity." Some items can be made in the school shop.

Material cost may be low where local sheet metal shops donate scrap. If purchased, stainless is no more expensive than the higher priced commonly used school shop metals such as copper.

Perhaps it would be best to introduce stainless in the senior high school metal shop. It would be handled by pupils in the 10th, 11th, and 12th grades. It may be used only as a "challenging" project for the more capable pupils.

The inclusion of stainless projects in an eighth and ninth grade metal shop is possible if careful selection is made.

Limitations

The extent of any school program is necessarily limited by the available facilities and the authorized budget. The report on shop procedures centers primarily around those which were developed in the metal shop of the Bend, Oregon senior high school.

Procedures

The problem was first attacked by the inclusion of a stainless steel project in the IE 487 Metalcraft Problems class instructed by Dr. H. O. Shorling and taken by the writer at the 1956 summer session at Oregon State College. The difficulty encountered indicated need for more information. School texts available did not cover the subject. The library was consulted for books on the subject. These were either historical or technically metallurgical in nature. Periodicals in the Engineering library gave information on use and industrial practices, but not much help for the school shop.

Manuals and booklets were obtained from the steel companies to determine if the techniques for industry could be adapted to the school shop. Experience in IE 487 indicated that some equipment should be made in the school shop.

Statement of Purpose

This research is based on experimental development of techniques for working stainless steel in the secondary school industrial arts metal shop. The purpose is to determine in a practical way whether this relatively new, but increasingly widely used, metal could be worked in a secondary school metal shop of limited facilities.

Definitions

A.I.S.I. American Iron and Steel Institute.

S.A.E. Society of Automotive Engineers.

Secondary school metal shop An industrial-arts type of shop including general metals, metalcrafts, and unit-shop metal work for grades 10, 11, 12.

Stainless Stainless steel.

Stainless steel Alloy steel of the A.I.S.I. Types 300 and 400 series.

Techniques Methods or procedures essential to expertness of execution.

CHAPTER II

THE MATERIAL, STAINLESS STEEL

History and Development

The form and flesh of modern industry and life might well be considered to hang on a skeleton of iron and steel.

And, as long as man has formed iron into the tools and structural forms which serve his needs he has been confronted with the problem of rusting, corrosion, and deterioration of this basic material, especially at elevated temperatures. Efforts to combat these problems of rusting and corrosion had for the most part been confined to surface treatment such as painting or plating.

Monypenny, in reviewing the history of stainless iron and steel (8, p.9-11), found that the earliest reference to the alloying of chromium with iron and the resultant resistance to corrosion was reported by Berthier in 1821. In 1838 Robert Mallet recorded the observation that of many metallic elements alloyed with iron, the addition of chromium produced the least corrodible alloy.

Again, in 1957 Fremy and in 1886 Boussingault reported favorable corrosion-resistant characteristics of chromium-iron alloys.

Unfavorable reports were made by Hadfield in 1892 and by Monnartz in 1911. Extremely strong sulphuric and hydrochloric acid solutions were used in these experiments.

After nearly one hundred years of but apparently casual interest in the chromium alloys the recognition of their corrosion resistant possibilities by Harry Brearley brought their first application in the cutlery industry (8, p.7-8).

Messrs. John Brown & Co., Ltd. and Messrs. Thomas Firth & Sons, Ltd., of Sheffield, England, had a joint research laboratory under the direction of Harry Brearley. In 1913 Brearley was investigating metal samples for rifles and naval guns, with particular interest in erosion resistance. Etching by reagents and microscopic examination was part of the research procedure. He noted a considerable difference in the reaction to the etching reagents for certain chrome alloys with different heat treatments. Further, he observed a very much prolonged resistance to the usual rusting and corrosion of the samples while in the laboratory atmosphere for long periods of time.

The possibilities for such a steel in the cutlery industry were readily recognized by Brearley, but it was the following year, 1914, before he could persuade a firm to try the new material. Ernest Stuart, cutlery manager for Messrs. R. F. Mosley, devoted considerable effort to developing the new techniques necessary for working this type of steel.

It is of passing interest to note that Brearley never patented this new "stainless article" (8, p.8) in England, but did obtain a patent in Canada in 1915 and in the United States in 1916.

Patented in 1913 were two series of chromium-nickel steels which approximate the present A.I.S.I. Type 300 series of stainless. But there seemed to be little development, application, or use of this type prior to World War I.

Thus the first decade of what might be termed "the stainless steel era" saw the development of high-chromium stainless steel comparable to our present A.I.S.I. Type 400 series. In addition to its acceptance by the cutlery industry, it found considerable use in the manufacture of engine exhaust valves before, and especially during, World War I (8, p.264).

Uses and Modifications

Following the Great War two additional industries began making parts from stainless steel.

Inherent advantages of stainless soon found it being used for steam-turbine blades. Techniques for forming and welding had to be worked out to make this application.

The steam-locomotive industry began using this new material for many of the parts, particularly of the engine. Possibly because of the experience of the internal combustion engine manufacturers with stainless steel exhaust valves, the steam-engine manufacturers adopted it first for valve mechanism use.

The last thirty years have seen ever widening fields of application and use of this modern material.

The characteristics of stainless steel make it popular for dairy, brewery, restaurant, and food processing equipment because it does not affect taste or flavor. Heat resistance as well as strength properties find it in use for gas turbine as well as steam turbine blades, anti-friction bearings, and jet plane parts. Corrosion resistance lends it to use in laundry, chemical, and oil industries. Toughness qualifies it for pump shafts, dental, and medical instruments. And its lasting, low-maintenance beauty finds it increasingly evident in architectural trim, siding, signs, and automotive trim. The latter industry is the largest single user of stainless steel.

From its original development and use, stainless steel is throughout the field of cutlery the master metal: tough, durable, and ever more beautiful in form and finish. The modern kitchen is replete with stainless. From the popular but expensive chrome plating of appliances, manufacturers are turning to fabricating from stainless. There are advantages over a plating which sometimes peels and sometimes wears through to the mild steel beneath.

Thus, it isn't surprising to read in the trade journal, STEEL, that stainless is second only to mild steel in production tonnage (5, p.159).

But the steel industry is confronted with a problem: How to meet this rising demand when one of the alloying elements, nickel, is in short supply? Additional research will be needed to find a replacement element. Stainless steel of the future may be modified from that which is available and in use today.

Chemical Composition

There has been some developmental change in the chemical composition of the stainless steel which is presently recommended for use in the secondary school metal shop, as compared with that patented by Harry Brearley over forty years ago. Quoting from Monypenny (8, p.8):

> ". . . it will be seen that the range of composition specified was 9 to 16 per cent. of chromium with carbon below 0.7 per cent. and preferably below 0.4 per cent. Certain other elements in limited amounts, up to 1 or 2 per cent., were also allowed as not affecting the result, . . ."

As will be noted in Figure 1, page 9, the excerpt from the 1955 S.A. E. Handbook (10, p.56) shows the A.I.S.I. Type 400 series of stainless steel recommended for cutlery use is quite similar to the original stainless steel patented by Brearley and introduced to the cutlery industry. This type of stainless steel is also known as a high-chromium iron.

Of wide use in the sheet form is A.I.S.I. Type 300 series of stainless, also shown in Figure 1, page 9. A common designation for this type is "18-8" which refers to the chromium (18 per cent) and nickel (8 per cent) content of the alloy. These percentages are not exact, but approximate the range permissible as will be seen in the chart. Further

Chemical Compositions of SAE Wrought Stainless Steels

SAE Number	Chemical Composition Limits %								AISI Type
	C	max. Mn	max. Si	max. P	max. S	Cr range	Ni range	Other elements	
30301	0.08-0.15	2.00	1.00	0.04	0.03	16.00-18.00	6.00-8.00	-	301
30302	0.08-0.15	2.00	1.00	0.04	0.03	17.00-19.00	7.00-10.00	-	302
30303F	0.15 max.	2.00	1.00	-	-	17.00-19.00	8.00-10.00	P,S,orSe 0.07min. Zr or Mo 0.60max.	303
*	*	*	*	*.	*	*	*	*	*
51410	0.15 max.	1.00	1.00	0.04	0.03	11.50-13.50	-	-	410
51420	0.30-0.40	1.00	1.00	0.04	0.03	12.00-14.00	-	-	420
*	*	*	*	*	*	*	*	*	*

Figure 1.

perusal of the chart indicates what Brearley discovered: i.e. that chromium, carbon, and nickel were the important elements in alloying stainless steel.

Physical Properties

Both the A.I.S.I. Type 300 and 400 series of stainless steel are tough alloys by nature of their chemical composition (6, p.306-308). Compared with mild steel, both types are poor conductors of electricity and of heat.

The 300 series of chromium-nickel stainless commonly called 18-8 type is non-magnetic. It is non-heat-treatable but is ductile and can be work-hardened from a basic tensile strength of 90,000 psi to as much as 260,000 psi. The hardness ranges from 120 to 480 Brinell.

Because of these characteristics, the stainless steels are difficult to machine. To improve machining qualities, A.I.S.I. Type 303 contains phosphorus, sulphur, or selenium as shown in Figure 1. page 9.

The A.I.S.I. Type 400 series of stainless steel are both magnetic and heat treatable.

Heat treatment information including annealing temperature range, hardening temperature range (where applicable), and quench are shown in Figure 2. page 11 for the recommended types of stainless for use in the school metal shop (10, p.120-121).

Heat Treatment of SAE Wrought Stainless Steels

SAE Steels	AISI No.	Full Annealing Temperature,F	Hardening Temperature,F	Quench
30301	301	1800 - 2100	-	Water or Air
30302	302	1800 - 2100	-	Water or Air
30303F	303	1800 - 2100	-	Water or Air
*	*	*	*	*
51410	410	1550 - 1650	1750 - 1850	Oil or Air
51420	420	1550 - 1650	1800 - 1850	Oil or Air

Figure 2.

CHAPTER III

EQUIPMENT AND TOOLS FOR STAINLESS IN THE SCHOOL SHOP

Quality and Adjustment of Tools and Equipment

Because of the nature of stainless steel, as discussed in Chapter II, the recommendations from industry are for good quality tools and equipment.

Raising hammers should be of forged steel. The toughness of stainless steel requires a tough, hardened tool to stand up in service.

The usual cast iron stakes are not adequate to stand the working of stainless. The stake needs to be of forged, hardened steel, or of cast iron with a hardened steel face.

Any cutting tool or equipment, such as shear or twist drill should be of high-speed steel.

> "Stainless steels are tougher than mild steels and require heavier and more powerful equipment. Experience has shown that stainless steels require a shear with a capacity 30% to 50% greater than would be used for plain carbon steels." (3, p.64)

The Type 400 series of stainless, sometimes called "chromium" stainless, may generally be handled the same as mild steel so far as shear blade adjustment is concerned.

The Type 300 series, also known as "chromium-nickel" stainless, is best handled by adjusting the shear blades more closely than for ordinary carbon steel (10, p.4).

"A recommended clearance for light gages of chromium-nickel stainless steels is 0.001" to 0.0015" and for heavier gages 0.0015" to 0.002". A closer clearance will tend to have a harmful effect on the blades because of scraping action. On extra thin gages it is sometimes necessary to operate with no clearance whatever, or an adjustment close enough to cut tissue paper."

Hand snips should be adjusted close and, if the gauge is very heavy, double cutting or compound lever shears should be used.

The same general rules apply to other shearing types of tools and equipment such as nibblers.

The rule of two to three teeth minimum in the kerf for cutting with a hacksaw must be closely observed when sawing stainless. The hacksaw frame should be well constructed and rigid.

Power metal-cutting band saws are excellent for contours. Operating instructions for the various types of metals including stainless should be followed.

If an abrasive cut-off wheel is used, the resinoid-bonded wheels are recommended at high speeds. The range suggested is from 10,000 to 16,000 surface feet per minute.

Center-punching should be done with a three-cornered punch and as lightly as the job will permit.

Twist drills will need to be of high speed steel and preferably of short twist and short length to reduce the tendency to chatter.

Standard taps will work, but for best results it is recommended that they be ground with a 15-degree hook. They may be purchased with this angle. It is suggested that a 50 per cent thread be cut because it will be easier to tap and will be of ample strength in most cases. Taps must be kept sharp and lubricated with heavy oil.

For machining in the metal-turning lathe, high-speed tool bits are recommended. Cemented carbide tools will permit higher turning speeds. Tools should be carefully ground and honed to keen cutting edges.

Care and Maintenance of Tools and Equipment

The care and maintenance of the tools and equipment used for working stainless steel was indicated in the previous section: (1) keep them sharp; and, (2) keep them properly adjusted.

An additional precaution is that of maintaining the shear table smooth. Irregularities impressed upon the surface of the stainless steel not only affect the finish, but leave work-hardened spots which may interfere with later cutting operations.

A corollary of item (1) above is that tools will have to be sharpened more often when working any quantity of stainless steel. They should always be carefully honed to a keen edge.

Adjustments should be checked often to keep them as recommended.

Tools and Equipment Made in School Shop

Most tools and equipment will be purchased and the recommendations of quality will need to be observed.

Some items can and should be made in the school shop. These would include hammers, stakes, and wooden forming and starting blocks. Since good quality forged hammers are available, they should be purchased.

Wooden forming blocks can be purchased or made from a stump or block of hardwood with the depression cut in the end grain. A hardwood such as maple may be used, either in the solid form, or built up by lamination and gluing.

In the Bend High School industrial arts shop, a block six inches square by ten inches long was made from salvaged desk tops. These were of maple. The pieces were ripped to width, joined, and planed. The pieces were then coated with glue, carefully stacked, clamped and left to dry.

The depression in the end grain was made by a shop-made tool in the drill press. A two-and-a-half inch section from a discarded file of 12 inch to 14 inch size was used. This was ground to a three-inch radius on one side. The radius may vary to suit the type of depression desired. Clearance was ground for normal right-hand rotation in the drill press. The blade was then centered and brazed into a slotted taper shank to fit the drill press. See Figure 3, page 16.

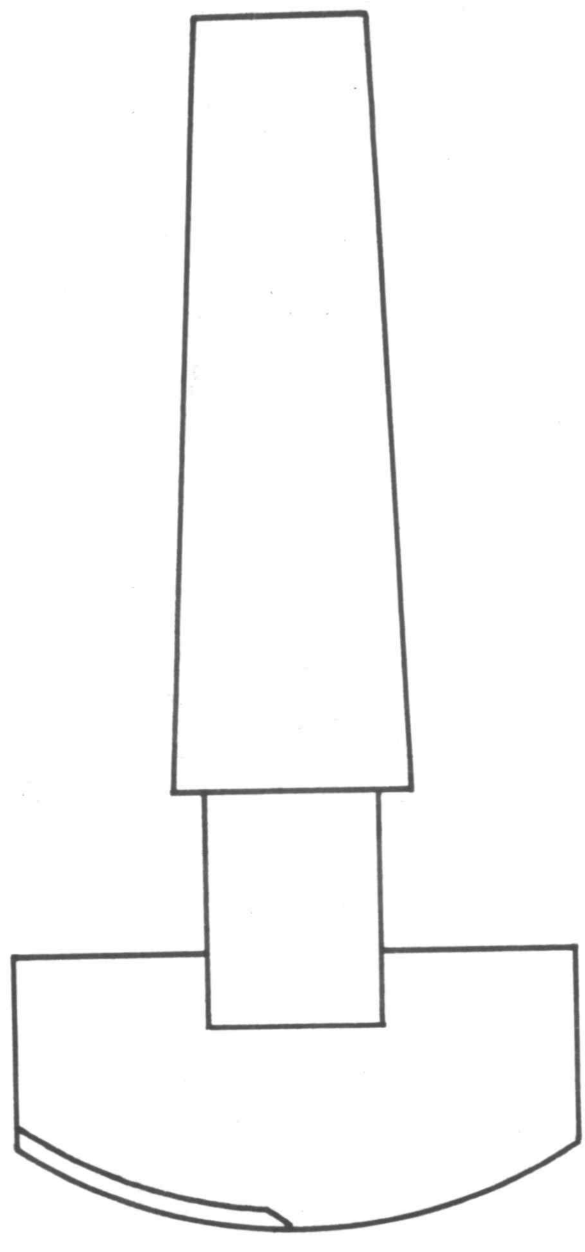

Figure 3.
Shop-made Tool for Cutting
Depression in Forming Block

Unless forged, tempered stakes can be purchased, they will have to be made in the school shop.

In the Bend shop this was done by first securing a broken truck axle from a local garage. The flanged end, plus about ten inches of axle shaft, was used. This part was cut off by using an oxy-acetylene cutting torch. A power hacksaw can be used, but experience in the Bend shop has too often revealed hard spots which ruin the saw blade and result in the use of the torch in the end.

The short flanged axle shaft was then put in the gas forge and heated to a white heat and allowed to cool slowly to anneal it.

The shaft end was then turned in the metal turning lathe to a diameter of one inch for a distance of two and a half inches.

The flanged end was turned to a mushroom shape for the head of the stake. The form can, of course, be varied to suit the purposes of the individual shop. The form could be square or rectangular and cut by a milling machine. It would be possible to cut the form with an oxy-acetylene torch and then carefully finish-grind it free-hand.

The turned, mushroom shape was first filed to remove the turning marks and then abraded to a smooth finish with an aluminum oxide industrial abrasive cloth. A coarse grit was used first and finally a No. 220 grit.

The mushroom was heated to a white heat and quenched in a five gallon bucket of tap water. Although a crack appeared in the shaft, the head was sound and hard.

The stake was remounted in the metal-turning lathe and again abraded to remove the scale which formed when it was heated.

Abrading was done from coarse to fine with a No. 400 grit as the final cloth abrasive used. The stake was then polished bright on a cloth wheel with "tripoli" as the polishing abrasive. See Figure 4, page 19.

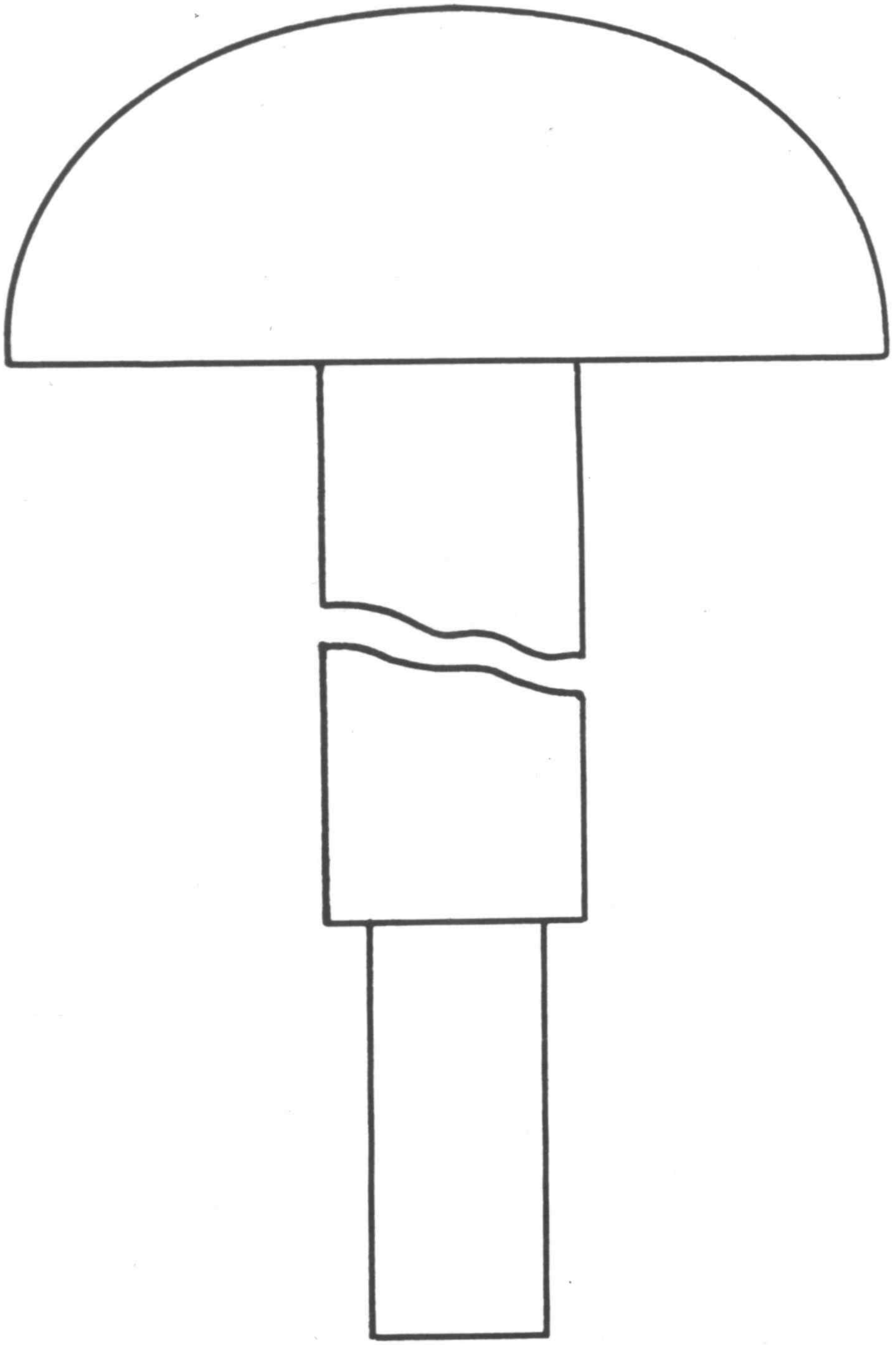

Figure 4. Shop-made Stake

CHAPTER IV

TECHNIQUES FOR WORKING STAINLESS

Cutting and Forming

In adapting industry procedures and recommendations to the school shop, the requirement of 30 per cent to 50 per cent greater capacity for a shear can be met by converse application. Check the gauge capacity of the shear and then limit its use for stainless to four or five gauges lighter material. For example, a shear with 16 gauge capacity in mild steel should not be used for stainless heavier than 20 gauge.

Stainless sheets available from local sheet metal shops will probably be 24 gauge to 28 gauge. This seems to be the range most commonly used in smaller commercial shops. The local school shop may secure this material in the form of short ends or scrap, either by donation or for less than the regular price per pound.

It will be noted that the extra toughness of stainless will require more force in operating the shear. As the cut is actually made in the material, it is noticeably more rapid than in mild steel. For these reasons, care must be exercised in properly positioning the piece to be cut and then in maintaining the position during the cut. Do not attempt to trim very close to an edge.

Circular blanks for hollowing bowls may be readily cut on a Beverly type shear. In operating this shear, side force on the handle should be maintained while proceeding with the cut. This is in conformance with the recommendation for close shear clearance. Because of the toughness of this material, there seems to be more of a tendency to "roll" when cutting stainless steel.

If the shop does not have a Beverly type shear, then a pair of compound lever shears would be advised. A good pair of straight snips can be used. In either case, they should be sharp and maintained for stainless work only.

The hand snip can be more effectively used to cut the stainless sheet by the technique of fastening one handle in a vise. Thus, the weight of the body can be brought to bear on the free handle as well as to exert side pressure to maintain essentially zero clearance between the blades of the shear.

The usual hacksaws available in the school shop are adequate for cutting stainless. Two cautions should be kept in mind:

(1) be sure to observe the recommended minimum of two to three teeth in contact in the kerf, and,

(2) be sure to saw with steady, firm strokes so that the teeth do not slide in the kerf without cutting.

The ductility of stainless is greater than that of mild steel (11, p.3). Its formability is excellent, but the greater strength requires greater force to form the metal.

It has, as a result, about twice the springback as mild steel.

The greater ductility permits sharp 90-degree and full 180-degree bends. Springback will not be as noticeable on the apron brake and a sharp bend as it will be when forming a radius.

The bending curve for any final form will have to be determined by experimentation for the particular application.

Drilling and Tapping

Twist drill recommendations call for high-speed steel with short twist and length.

High speed steel bits seem to be the most prevalent in use. Most high school shops have this type. If the shop were not so supplied, it would be necessary to purchase the sizes needed for stainless steel work.

As the drill bits are worn, chipped, and re-sharpened in general shop work they are reduced in length. These short drill bits may be retained especially for stainless work.

While the recommendation of industry is for a short-twist drill bit, the usual twist drill found in the school shop is satisfactory. In industry it is a production problem but in the school shop the relatively limited use does not require a special twist drill.

Four recommendations for drilling stainless in the school shop are:

(1) keep the drill bit sharp,

(2) use plenty of coolant, preferably sulfurized or chlorinated oil,

(3) run the drill press at about half the speed recommended for mild steel,

(4) always supply sufficient pressure to <u>keep the bit cutting</u>!

These recommendations were followed in the Bend school shop and found to work satisfactorily.

The admonishment to "keep the bit cutting" is because of the work-hardening characteristics of chromium-nickel stainless. Withdrawal of the drill bit should be done quickly. Riding of the drill bit without cutting will cause hardening in the bottom of the hole and difficulty in starting the cut again.

When tapping, use a new, sharp tap and carefully grind a 15-degree hook-grind on the entering threads. Because of the extra strength of stainless, a 50 per cent thread should be ample for most school projects.

Coolant recommendations are the same as for drilling. Use a sulfurized or chlorinated oil.

<u>Hollowing</u>

Compressive working of chromium-nickel stainless sheet causes work-hardening, therefore it is recommended that stainless steel not be used for raising.

The greater ductility of stainless lends it readily to the formation of bowls by the hollowing process. The hollowing process streatches the metal rather than changing it by compression or upsetting.

The procedure for hollowing stainless is the same as for other craft metals, such as copper, with two main exceptions:

(1) the extra toughness of stainless requires a heavier hammer and heavier blows to stretch the metal as it is driven into the depression of the wood block,

(2) when driven forcefully, it was found that no annealling was needed between courses.

Bowls were hollowed in the Bend school shop requiring from five to seven courses without the need for annealling.

In bouging and planishing stainless, the toughness of the metal carries the blow through to the stake. The toughness also requires heavier blows. For these reasons, cast iron stakes will be damaged. It is necessary to use a hard-surfaced stake. The shop-made stake described in Chapter III was made in the Bend school shop and stands up well in service.

Soft Soldering and Silver Brazing

Soldering procedures for tin plate, copper, and mild steel and the soldering supplies usually on hand in the school shop for such metals will generally not be satisfactory for soldering stainless steel.

Surface preparation is the same as for mild steel. Degrease the metal, and if it is a polished surface roughen it with a file or abrasive. This improves molecular adhesion.

While 50-50 solder commonly used for mild steel can be used on stainless, it is strongly recommended that a 70-30 solder be used (13, p.45). That is 70 per cent tin and 30 per cent lead. The use of 70-30 solder for stainless is preferred because:

(1) the lower melting point produces less discoloration of adjacent metal,

(2) better "wetting" properties are evident,

(3) better corrosion resistance of the solder is comparable to the stainless itself.

It is very important that the right type of flux be used for successful soldering of stainless steel. This is due to the necessity of cutting through the chromium oxide film on the metal. It is recommended that a good commercial flux especially for stainless be purchased (13, p.46).

The Bend school shop purchased Allen Stainless Solder and Allen Flux. These worked very well.

Suggestions for techniques of soldering stainless are:

(1) if the job permits, it would be advisable to "tin" the edges with a film of solder before joining them,

(2) use a large soldering copper and take more time for the heat to penetrate because stainless has a lower coefficient of conductivity than mild steel,

(3) do not over-heat, use only enough heat to melt and flow the solder,

(4) wash immediately with plenty of water to dilute and carry away the strong acid.

As with soft soldering, some of the usual procedures for silver brazing should not be used on stainless steel.

The melting point of the silver solder should not be higher than 1200 degrees Fahrenheit and the alloy analysis should be close to the following (13, p.47):

Silver . . . . . 50 per cent
Cadmium . . . . 18 per cent
Zinc . . . . . . 16.5 per cent
Copper . . . . . 15.5 per cent

The flux used should be that of the manufacturer of the silver solder. By following the directions of the manufacturer a satisfactory job can be accomplished.

Following the soldering, thoroughly wash with plenty of water to remove any trace of the flux.

Surface Finishing

The first consideration in surface finishing should be care in handling prior to finishing in order that scratches and marks might be reduced to a minimum.

Industry recommends the use of lubricants with abrasive finishing of stainless. Few school shops may be so equipped.

Finishing can be done satisfactorily with abrasive strips and rubber-backed wheels. Aluminum oxide is preferred, although silicon carbide can be used. While a speed of 6,000 to 8,000 surface feet per minute is recommended, a speed of 5,500 surface feet per minute was used with good results in the Bend school shop.

In progressing from coarse to fine grits in the finishing sequence, it is best not to change by more than 40 grits for succeeding operations; for example, 80 grit to 120 grit.

A commercial satin-like finish is produced by 150 grit and hand block.

Techniques to be emphasized in school shop procedure are:

(1) do not try to cut too fast because heavy pressure causes overheating and tends to cause buckling and discoloration of the metal,

(2) never attempt to remove too much metal with a fine abrasive because it is better to use the coarsest grit size consistent with the finish desired,

(3) keep abrasive scratches straight and parallel.

If buffing is to follow abrading, the final grit for abrading should be 240 to 280. For extra bright finish, industry recommends buffing with chromium oxide rouge. For the school shop a finish using "tripoli" would in most cases be satisfactory. There should be extra emphasis on correct buffing procedures.

If, in any of the processes, steel wool is to be used it must be a stainless steel wool. Never use ordinary steel wool. The surface will be contaminated with minute particles of ordinary steel which will rust and discolor the finish of the project.

A final cleansing of a project can be done with soap, water, and such cleansers as Bon Ami, Bab-O, or Old Dutch Cleanser. The bright, durable, natural finish of stainless requires no protective coating of any kind.

CHAPTER V

SUMMARY AND CONCLUSIONS

Stainless steel is a relatively new metal alloy. The characteristics of heat resistance, corrosion resistance, and toughness have increased its use in many applications. From the cutlery industry, its desirable qualities brought it into the steam-locomotive and steam-turbine industries. Today, it is widely used in the dairy, brewing, chemical, oil, food processing, medical, architectural, automotive and many other industries. Fine cutlery, kitchen utensils, home appliances are being increasingly fabricated from stainless.

With production tonnage second only to mild steel, it would seem reasonable that this alloy should be added to the media found in the secondary school industrial arts metal shop.

In order to successfully handle this new material in the school shop, research into the procedures, practices, and recommendations of industry were first necessary. Experimentation to adapt these procedures and develop techniques for the school shop then followed:

(1) if new equipment is being purchased, it should be of good quality,

(2) tools and equipment used for stainless work should be kept sharp and properly adjusted,

(3) some equipment, such as hollow-ware stakes, may need to be made in the school shop from tougher, harder material than the usual stakes of cast iron,

(4) with some modification, cutting, forming, drilling, and tapping can be done with the usual school shop tools and equipment,

(5) the ductility of stainless readily adapts it to hollow vessel projects,

(6) satisfactory soft soldering and silver brazing require special stainless steel supplies, and,

(7) surface finishing can be accomplished by careful use of the usual school shop equipment and supplies.

The differences between handling mild steel and stainless steel are sufficient to cause difficulty. Adaptations from industry procedures can be accomplished to a sufficient extent to make stainless projects practical in the limited facilities of the secondary school metal shop.

By observing the recommendations outlined above, it is felt that 10th, 11th, and 12th grade pupils can successfully include stainless projects in their school metal shop work. The toughness of stainless would be a challenge to the pupil's ability and skill. The instructor might wish to limit the stainless projects to use as challenging projects for the advanced classes or for the better pupils in a class. With careful selection by the instructor, it is possible to include some limited stainless work in a junior high school metal shop.

This experimental research does not presume to be exhaustive. It concerns basic problems confronting the person working stainless for the first time in the school shop. Much additional experimentation can and should be done to develop techniques which will help bring about inclusion of this new media in the industrial arts metal shop program.

Areas in which the writer suggests additional research and experimentation are:

(1) piercing, whether the normal school metal shop equipment would be adequate or not, would bear investigation

(2) welding supplies and techniques for stainless steel

(3) metal spinning, possibilities of handling stainless in a school shop by this highly skilled operation

(4) projects for a secondary shop, development of a series appropriate to that pupil level and the limited facilities of such shops

(5) projects for junior high school metal shops, careful selection and experimentation to determine the extent of adaptability to this grade level.

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